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EVALUATION OF TRAFFIC NOISE BARRIER DESIGN METHODS

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16. Abstract

This interim report presents a procedure to statistically evaluate traffic noise barrier design method performance by estimating the average difference between predicted and measured insertion loss of an actual barrier as a function of a reference level unaffected by the barrier before and after construction. An elaboration of the procedure is described to identify possible weaknesses in the barrier design methods. The procedure relies on field noise surveys at selected measurement positions before and after construction and analysis of covariance. The methodology and results of before noise measurement surveys for barriers to be built along the Garden State Parkway are presented.

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SUMMARY

Traffic noise abatement is becoming a factor in highway design. Acoustic barriers between roadway and noise sensitive receptors are effective abatement measures and a number of traffic noise barrier design methods are available.

This study evolved from the need to evaluate the barrier design methods for overall accuracy in the field, relative to one another. This report summarizes the formulation of an approach to reliably evaluate insertion loss computed from the various barrier design methods at specific sites over ranges of traffic conditions encountered in the field. The report details the evaluation method finally selected and the procedure developed to apply the method. Based on covariance analysis, the evaluation method relies on traffic noise surveys conducted before and after barrier construction with the roadway present. The insertion loss of the actual barrier, for a variety of traffic source conditions, is indirectly compared to that predicted by the barrier design methods with stated statistical precision.

The development of the evaluation method comprised Phase I of this project. Implementation of the method will take place in Phase II of the project, during which traffic noise surveys are to be made at several barrier sites in the field both before and after barrier construction. Phase II has been partially completed. To date, proposed barrier sites have been selected and before construction traffic, weather, and noise data have been collected for them. Field measurement equipment, procedures, and results are described in this report for the before barrier construction noise surveys.

INTRODUCTION

Objective

Traffic noise barriers can be effective noise control devices if utilized properly. Several states throughout the country are now planning to employ this method of noise control, and have constructed or proposed construction of noise barriers along a number of state and interstate roadways. However, the cost of noise barriers can be greater than $100 per linear foot, and it is, therefore, important before construction to use an accurate method to design a barrier, since an error in designed noise level attenuation of a few decibels may result in the construction of a noise barrier much longer and higher than necessary. Thus it is the objective of this study to evaluate the performance of the major barrier design methods currently in use (including NCHRP Report 174 - Design Guide for Highway Noise Prediction and Control, Reference 11, the Michigan Traffic Noise Level Predictor Computer Program, Reference 12, and the Transportation Systems Center (TSC) Traffic Noise Prediction Computer Program, Reference 13) to determine the accuracy of these methods in certain situations, and if possible to indicate the areas in which each method is deficient so that feasible modifications and improvements may be made.

This project has been divided into two phases: Phase I, the development of an effective method of measuring barrier insertion loss (that is, the change in L_{10} or L_{eq} resulting from a traffic noise barrier placed between the roadway and observer near the roadway) and evaluating design methods, and Phase II, the actual taking of measurements and evaluation of the design methods. Soon after the start of the project, the Department let plans to construct barriers along the Garden State Parkway. A part of the field measurement portion of Phase II was therefore conducted concurrently with Phase I. This

report includes an explanation of the results from Phase I of the project, which is now complete, and the before barrier construction data taken for Phase II of the project.

Background

An investigation of studies of barrier attenuation and work done on barriers by independent groups and by state agencies in states which had begun programs showed that no method of measuring the insertion loss of a barrier was at that time being used which yielded results attributable solely to the effect of the barrier. The two main methods of measuring insertion loss were: 1) to measure noise levels behind the barrier and compare them with noise levels determined from any one of a number of prediction methods, and 2) to make noise measurements before construction of the barrier and compare them with measurements made after construction. Both of these methods, however, are open to question: The first depends on the accuracy of the prediction method used (which even today is not well known for the most often used methods), and the second will be in error if the noise source is significantly different at the times the before and after measurement are made. Also, in very few of the studies was an attempt made to take these factors into account.

Shortly after the above investigation, meetings were held with members of the Federal Highway Administration, during which the NJDOT expressed an interest in the development of an effective method of measuring barrier insertion loss. This proposal was combined with an FHWA aim to evaluate barrier design methodologies, and plans for this project were drawn and approved. The procedure outlined here will be used to meet the specified goal.

DIFFICULTIES INVOLVED IN EVALUATION OF DESIGN METHODS

Discussion of Difficulties

Evaluation of the design methods is to be carried out, as one would expect, by comparing the insertion losses predicted by the design methods against actual insertion losses measured for a number of barriers in different situations. Each design method will then be evaluated in terms of its overall predictive capabilities, its performance in various physical situations, and its performance in relation to other design methods.

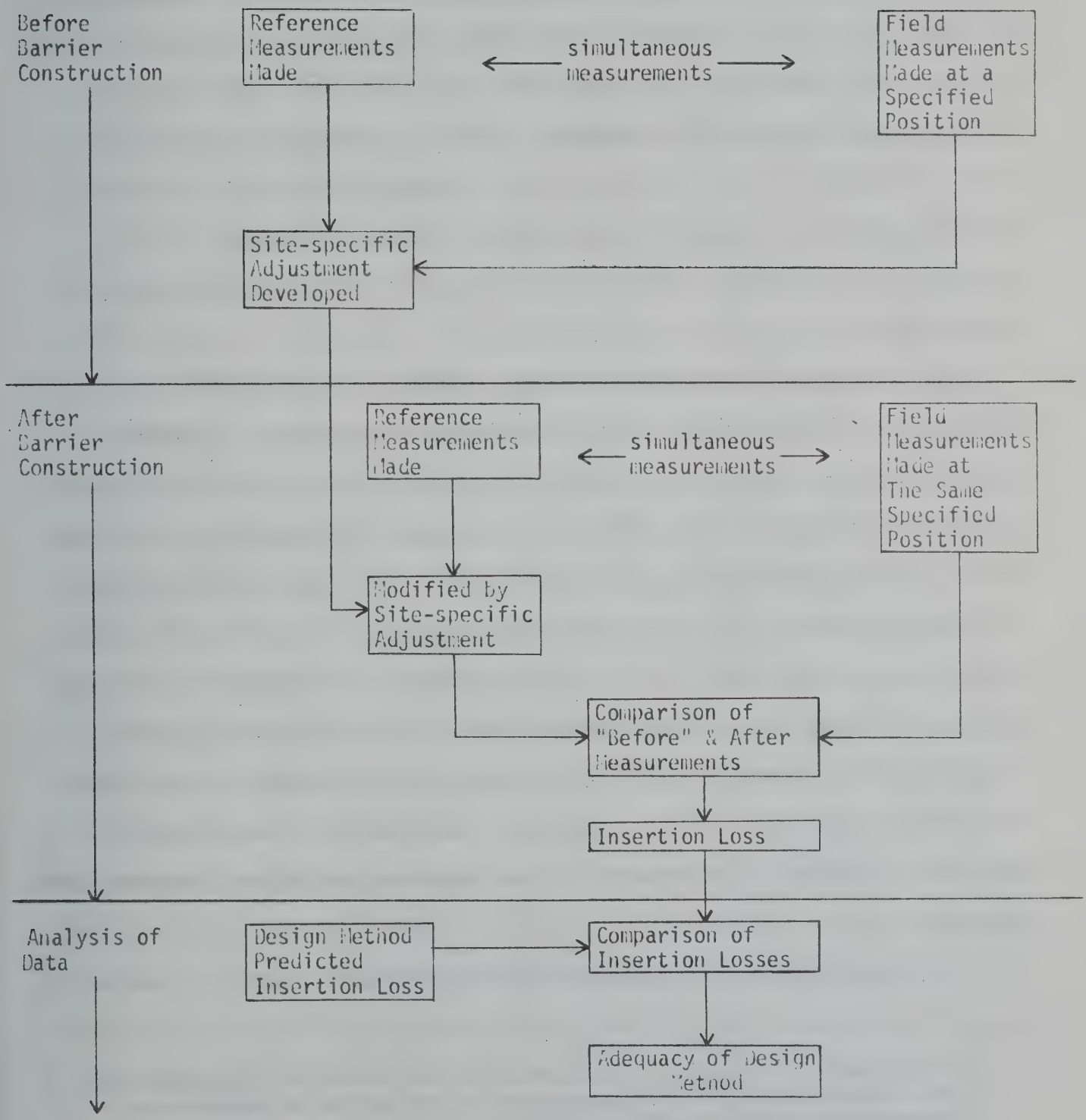
The measurement of insertion loss, however, is unfortunately not a straightforward procedure. For example, a traffic noise measurement made before a barrier is built cannot be directly compared with a traffic noise measurement made at the same position after the barrier has been built, simply because a difference in traffic source itself during the two measurements may account for a significant part of the difference noted between the two measurements. Measurements at two different positions, one with a barrier and one without, cannot be directly compared, even for the same traffic,since differences in the terrain may account for some of the difference in the measurements. Conceivably, meteorological conditions, and perhaps other factors, may enter into the picture. And finally, even when an attempt is made to take these effects into account, it is difficult to know or specify whether it has been done adequately.

Clearly, many problems must be overcome before a reliable measure of insertion loss can be obtained. One method which can adequately resolve these problems, however, is the following (See Figure 1): Before construction of the barrier, many "field" noise measurements are taken at a given position behind the proposed barrier. With each one, a simultaneous measurement is made

Figure 1

Flow Chart of Example Evaluation Procedure

(for each field position)



at some specified "reference" position (the reference position chosen so that the traffic noise at that position will not be affected by the barrier after its construction). The entire set of measurements is made only under site conditions, (e.g. meteorological conditions) which do not vary enough to significantly affect the noise levels measured. From the pairs of corresponding measurements, an "adjustment" is developed which can be applied to the reference levels measured to give the field levels measured. This adjustment takes into account any traffic parameters (that is, any source variables, such as the number of cars) which have had a discernable effect on the levels measured (actually, on the difference between the levels measured).* In addition, it is designed so that the error inherent in its application can be specified.

After the barrier has been constructed, another set of simultaneous measurements is taken at the same field and reference positions. To monitor any change in site conditions, a control site unaffected by the barrier before and after barrier construction will also be surveyed. The insertion loss of the barrier for any measurement may then be found by 1) using the method developed previously to adjust the reference measurements (since it is unaffected by the barrier) to the field level which would have existed if the barrier had not been built, and 2) comparing this derived field level to the field level measured, since the derived level has been obtained under similar circumstances and takes into account variations in traffic patterns. The result will be a value for insertion loss which can be compared to that predicted by the design methods to be evaluated.

As is readily seen, this method effectively solves the problems involved

*If the source has changed, it is not true that measuring the same noise level twice at one position guarantees the corresponding measurements at some other position will be the same.

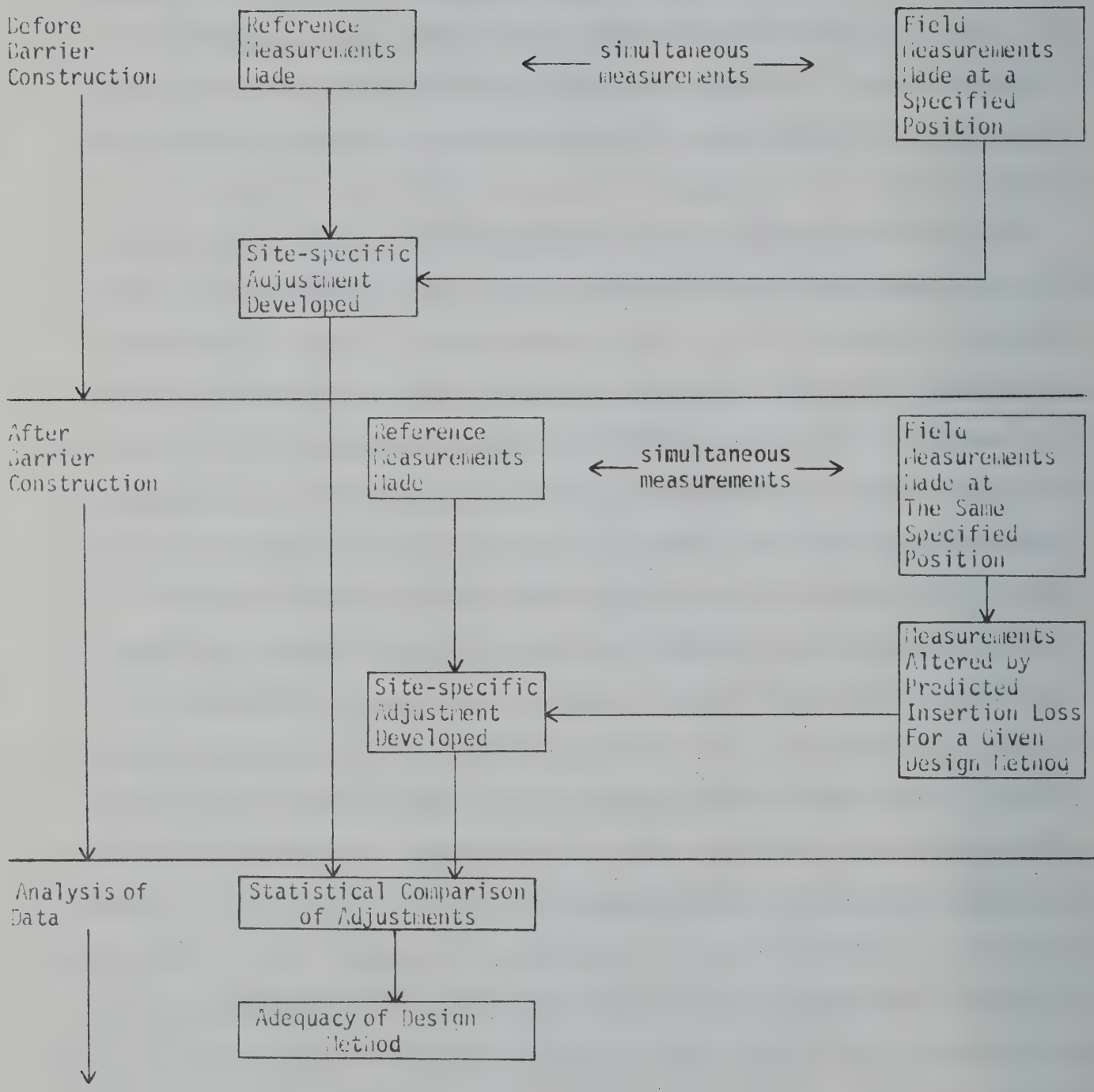
in the measurement of insertion loss. Terrain differences will not be considered explicitly and should have not changed significantly except for the barrier afterwards. Variations in the source during the before and after measurements are automatically taken into account by the adjustment made, since it will be designed for this purpose. Meteorological effects can be neglected, since all measurements have deliberately been made during similar conditions. And finally, one can specify the accuracy of the figure obtained for the insertion loss, since the accuracy of the adjustment itself is known.

The first phase of the project was primarily concerned with the development of the "adjustment" described above, and how the evaluation of the design methods was to be carried out. After consideration of a number of practical and theoretical aspects of the problem, it was decided that the most effective way to evaluate a given design method would be to increase each "after" measurement by the insertion loss predicted by the design method for that measurement, so that the result would be essentially a set of "before" measurements for the traffic conditions under which the measurements were made. An adjustment relating reference to field values would then be developed for this data, and compared to the adjustment made to the data actually taken before barrier construction. (See Figure 2). If the design method being tested adequately predicts barrier insertion loss including ground effects, there should be no significant difference between the two adjustments, and this can be statistically checked. This method of evaluation also overcomes the difficulties noted above. If ground effects are not predicted, barrier attenuation is the result. Ground effects must be estimated to compute measured barrier attenuation. A complete explanation of the measurement and analysis method developed is given in "Details of the Evaluation Procedure".

Figure 2

Flow Chart of Data Analysis Evaluation Procedure

(for each field position)


Before Barrier Construction
Reference Measurements Made
simultaneous measurements
Field Measurements Made at a Specified Position
Site-specific Adjustment Developed
After Barrier Construction
Reference Measurements Made
simultaneous measurements
Field Measurements Made at The Same Specified Position
Measurements Altered by Predicted Insertion Loss For a Given Design Method
Site-specific Adjustment Developed
Analysis of Data
Statistical Comparison of Adjustments
Adequacy of Design Method

Development of an Evaluation Procedure

The first step in the development of a method to accomplish the objective of this project was a study and review of literature pertaining to the principles of noise propagation and barrier attenuation in general and the parameters which must be taken into account in the measurement of insertion loss. A list of the literature included in the study is contained in the bibliography.

In the light of this study, decisions were made regarding the optimum placement of field microphones for evaluation of the barrier, the placement of the reference microphone to insure its independence of the barrier, and the duration of each traffic noise measurement necessary to derive a meaningful L_{10} and L_{eq} from the data. (A five-minute measurement period was judged sufficient; the placement of the measurement microphones is more easily described in the section entitled "Acquisition of the Before Construction Data" below.)

The most important decision to be made concerned the way in which relevant parameters were to be included in the adjustment to the reference measurements; it was decided to employ statistical methods - specifically, a linear regression - to accomplish this. (For the reader unfamiliar with statistical analysis, a short explanation of linear regression is provided in Appendix A). A number of possible ways of performing the regression were proposed, and the most promising of these were developed further. This development included a computation of the precision which could be assigned to the insertion loss measurements (in terms of confidence intervals), a comparison of the adjustments based on the amount of information yielded from the same input data, and a consideration of whether the type of information resulting from the regression methods was suitable for the intended application. Finally a method was selected which was regarded as best by these criteria. This is the method which is explained in detail here, and which will be used in the analysis of the data.

DETAILS OF THE EVALUATION PROCEDURE

General

The method specified will meet the previously stated project objective. To restate, it will statistically compare predicted barrier insertion loss to measured barrier insertion loss at a set of sites among different barrier design methods over the range of traffic conditions encountered in the field. In terms of the foregoing discussion, four basic elements in this restatement may be identified:

1) Sites
2) Traffic conditions
3) Comparison descriptor
4) Statistical model

The essentials of the method developed may be explained relative to these elements. Briefly, the method will consider a specific site to consist of two microphone positions, reference and field, at which noise levels, either L_{10} or L_{eq}, are observed by taking independent samples before and after barrier construction. Traffic conditions observed at a site will be specified for the method by the reference levels and simultaneously recorded source traffic variables such as volume and speed, or functions thereof.

The comparison will be described in terms of the numerical difference between predicted and measured barrier insertion loss for a particular barrier design method at given reference level. The statistical model, a special case of covariance analysis, will functionally relate these differences between predicted and measured insertion loss with reference levels. Estimates of the random error from the experimental design will permit test of the null hypotheses - Hypothesis A: There is no difference over the whole range of traffic conditions encountered and Hypothesis B: There is no difference over

particular ranges of these traffic conditions.

A characteristic of the method is that both predicted and measured insertion loss are not required as separate functions of reference levels. Rather, the difference between predicted and measured insertion loss as a function of reference level is computed from the difference between the after barrier construction field levels increased by the predicted insertion loss for a particular design method and the before construction field levels as separate functions of reference levels. The after field levels increased by the predicted insertion loss are considered to be before field levels (without the barrier in place) as predicted by the particular barrier design method under test. On the average for a given reference level, these predicted before field levels behind the barrier after construction are indeed comparable to the average field levels measured before construction. The average predicted and measured before field levels are then determined by adjustments to reference levels, derived from simple linear regressions. The average measured insertion loss as a function of reference level is additional information that will be supplied for each site in a separate but similar procedure.

The method will provide a yes or no answer (in a statistical sense) for Hypothesis A, the question of whether a particular barrier design method works over the whole range of traffic conditions studied. This will be the most sensitive test on the data. The test also provides a means of grouping barrier design methods for a particular site into two basic groups - "yes", it predicts and "no", it doesn't. Taking all chosen sites together, each site's "yes/no" grouping represents an independent test of the barrier design method on a common basis. The design method may be evaluated with respect to frequency of appearance in the "yes" group overall. This particular test of hypothesis will also indicate if a non-zero constant difference between predicted and measured insertion loss exists for a particular site and design method. A conditional

"no" group for constant difference may also be used to evaluate the design method.

The less sensitive test on the data concerns Hypothesis B, the particular range of traffic conditions over which the barrier design method predicts (in a statistical sense). It is less sensitive because it attempts to give specific information about the differences for any reference noise levels. Because of the lack of sensitivity, it has a tendency to fail to reject the null hypothesis more often. The range of traffic conditions over which the null hypothesis is rejected may be used to supplement the evaluation of barrier design methods. Specific areas of deficiency may also be identified in the design methods from this range.

In succeeding sections, details will be given concerning 1) the difference between predicted and measured insertion loss 2) the statistical model relating these differences to reference levels and 3) the influence of traffic variables on the differences. A complete procedure and flowchart of the steps implementing this approach to insertion loss prediction and measurement comparison is given in Appendix B.

Difference between Predicted and Measured Insertion Loss

The difference between measured and predicted insertion loss will be defined indirectly at a particular site from the difference between field noise levels, before barrier construction, and field noise levels after barrier construction, increased by different barrier design methods' insertion loss predictions to before construction levels. The indirect approach is necessitated by the way data was collected.* Consider that the complete data for a

*The sampling scheme is a special case of a completely randomized experimental design with respect to the field values (Reference 8, Section 12.2).

particular site consists of one sample of field levels LB_f, and corresponding reference levels, L_r, and traffic variables, TV (implying TV_1, TV_2, ,,,,, TV_k) measured before barrier construction, and another sample, independent of the first, of field levels, LA_f, and corresponding reference levels, L_r, and traffic variables, TV, measured after barrier construction.

The barrier design methods are aware only of traffic variables, TV, in the before and after samples. They are not aware of corresponding reference levels, L_r, in either the before or after samples. Known values of traffic variables that happen to produce particular L_r are used in the design methods to compute a paired (simultaneous) predicted before level, LB_p (without barrier, including ground effects), and predicted after level, LA_p (with barrier), at at the field positions. The predicted insertion loss, I_p, is simply computed as the pairwise difference.

$$I_p = LB_p - LA_p \qquad (1)$$

The insertion loss, I_p, may vary with traffic condition L_r, TV) or may remain a constant for all traffic conditions depending on the barrier design method. Consequently, when a particular design method is used to predict barrier insertion loss, I_p, from measured traffic variables, a degree of correlation (which may be zero) exists between I_p and L_r. Because of this, I_p could be explicitly related to L_r for before or after data. Then predicted insertion loss could be directly compared for given L_r to measured insertion loss explictly related to L_r in a similar fashion.

The measured insertion loss, I_m, can hypothetically be expressed as the pairwise difference between field levels without the barrier in place, LB_f, and field levels with the barrier in place, LA_f, measured simultaneously for the same traffic source:

$$I_m = LB_f - LA_f$$

These field levels are correlated because of the assumption of paired (simultaneous) sampling. Both are correlated to L_r, also simultaneously measured; therefore, I_m is correlated to L_r.

In reality, LB_f and LA_f cannot possibly be simultaneously measured in the field. In fact, it has been stated that independent (unpaired) samples of LB_f and LA_f before and after are taken. However, with each observation of field level, the reference level, L_r, is observed. L_r acts as a control variable for the before and after field measurements through which they can be related, as will be shown.

The difference, D, between predicted and measured insertion loss may now be directly computed as:

$$D = I_p - I_m \qquad (3)$$

This difference is the quantity which measures the performance of the barrier design method against measured levels. From equation (2), this difference may also be expressed as:

$$D = I_p - (LB_f - LA_f) \qquad (4)$$

Through I_p, LB_f, and LA_f, the difference D is correlated with the simultaneously measured L_r and traffic variables TV. In this hypothetical expression, note that I_p, LB_f, and LA_f are simultaneously obtained for precisely the same traffic condition (L_r, TV). But, in fact, only independent measurements of LB_f and LA_f may be taken, as mentioned previously. Therefore, I_p may be computed from traffic variables measured with either LB_f or LA_f, but not both at the same time.

In order to devise an expression for the difference between predicted and measured insertion loss that can utilize independent samples of LB_f and LA_f, consider rather the average difference, $\overline{D}$. This is the expected value of the distribution of source traffic variables, TV, that can produce the particular L_r

To this end, a new field level based on the after sample will be defined:

$$LP_f = LA_f + I_p \tag{5}$$

where I_p is computed only from the after traffic variables, TV, measured with corresponding L_r. The noise level LP_f, represents the field level, LB_f, that would have been measured without the barrier in place and simultaneously with LA_f. The predicted barrier insertion loss acts as an additive adjustment to LA_f. This adjustment is implicitly a function of traffic variables, TV, known at the time LA_f was measured. The after field level is known exactly (ignoring measurement errors), so are the traffic variables required by the barrier design method. LP_f is consequently correlated to L_r measured in the after sample.

The difference between LP_f and LB_f is simply D, the difference between predicted insertion loss I_p, and measured barrier insertion loss I_m, using equations (5), (2), and (3):

$$LP_f - LB_f = LA_f + I_p - LB_f$$

$$I_p - (LB_f - LA_f) = I_p - I_m = D$$

therefore,

$$D = LP_f - LB_f \tag{6}$$

Since the comparison descriptor has been defined as the average difference D as a function of L_r, assume D, LP_f, and LB_f are random variables with averages (expected values) $\overline{D}$, $\overline{LP_f}$ and $\overline{LB_f}$. Therefore, $\overline{D}$ may be computed from the expected values of equation (6):

$$\overline{D} = \overline{LP_f} - \overline{LB_f} \tag{7}$$

Now $\overline{D}$ may be estimated either from one sample of paired observations of LP_f and LB_f for a range of after traffic conditions, L_r and TV, which cannot be done here, or from two independent samples of LP_f and LB_f, over a range of

before and after traffic conditions, which can be done, (Reference 8, Chapter 8). The after construction measurements will provide estimates of $\overline{LP}_f$, while the before construction measurements will provide estimates of $\overline{LB}_f$.

Note that measured barrier insertion loss, I_m, need not be computed as a function of L_r for comparison purposes. Indeed, since barrier design method results are not expressed in the context of reference levels per se, measured barrier insertion loss as a function of L_r is not needed for comparison purposes. Unless predicted insertion loss Ip is explicitly tied to L_r no comparison can be made. The connection is accomplished by specifying those values of traffic variables which produce given L_r to the design methods. The connection is implied in $\overline{D}$ by the after sample of traffic variables measured simultaneously with L_r and used to obtain values of LP_f.

Statistical Model

The basic statistical model to test the difference between predicted and measured insertion loss for a given site and barrier design method will be developed as a special case of analysis of covariance. As applied to this study, the analysis compares the dependent variables from two simple linear regressions obtained from statistically independent samples of data having a common independent variable. These regressions comprise the explicit adjustment of reference levels to field levels. One regression will be $\overline{LB}_f$, the average field level before construction, versus L_r, the reference level. The other regression will be $\overline{LP}_f$, the average before construction field level that would have been obtained after barrier construction, as determined from traffic variables by a given barrier design model, versus L_r.

The two regressions are assumed to be of the form:

$$\overline{LB}_f = \beta_B L_r + \alpha_B \qquad (8)$$

$$\overline{LP}_f = \beta_p L_r + \alpha_p \qquad (9)$$

The average difference $\overline{D}$ between predicted and measured insertion loss, therefore, becomes:

$$\overline{D} = \overline{LP_f} - \overline{LB_f} = (\beta p - \beta_B)L_r + (\alpha p - \alpha_B) \quad (10)$$

Here average values $\overline{LP_f}$ and $\overline{LB_f}$ are given as linear functions of L_r with slopes βp, β_B and intercepts α_p , α_B respectively. Further, any value of field level may be expressed as the sum of the average level plus a random error, e, for a given value of L_r:

$$LB_f = \overline{LB_f} + e_B \quad (11)$$

$$LP_f = \overline{LP_f} + e_p \quad (12)$$

The errors e_B and e_p are assumed to have normal distribution with averages equal to zero and variances, σ_B^2 and σ_p^2. Estimates of the variances σ_B^2 and σ_p^2 for the LB_f and LP_f regressions are given by squares of the standard error of estimates S_B^2 and S_p^2, respectively.

The average difference $\overline{D}$ is also seen to be a linear function of L_r. Its slope and intercept are simply given by the difference in slopes and intercepts of the LB_f and LP_f regressions. In addition, any value of difference may be expressed as the average value plus random error e_D for a given value of L_r:

$$D = \overline{D} + e_D \quad (13)$$

The error e_D is also assumed to have a normal distribution with average equal to zero and variance, σ_D^2. However, the variance σ_D^2 is determined by the variances of the two regressions σ_B^2 and σ_p^2. Thus σ_D^2 is estimated from functions of S_B^2 and S_p^2.

Using the estimated variances of the error distributions, the basic statistical model permits tests of the null hypotheses. Hypothesis A: $\overline{D} = \overline{LP_f} - \overline{LB_f} = 0$ for all L_r, is tested by independently testing with t-tests, two null sub-hypotheses on slopes and intercepts, i.e., equal slopes: $\beta_p - \beta_B = 0$,

and equal intercepts: $\alpha_P - \alpha_B = 0$. Hypothesis A is rejected when either sub-hypothesis is rejected. However, if the hypothesis of equal slopes fails to be rejected when the hypothesis of equal intercepts is rejected, a non-zero constant difference between predicted and measured insertion loss is indicated. Further, if the power of the t-test on equal slopes (See Appendix B) is sufficiently high, then a constant difference over the range of regression will be computed with associated confidence limits. This constant difference may be used to correct predicted barrier insertion loss at a site. (The power of the t-test on equal slopes, incidentally, may be used to determine the before and after sample sizes required to achieve any desired accuracy or sensitivity with the proposed method.)

Tests of the null Hypothesis B: $\overline{D} = 0$ for particular L_r are made when Hypothesis A is completely rejected. Hypothesis B is tested by using confidence intervals about the difference $\overline{D}$ as a function of L_r, derived from the theory in Reference 7, Section 2. These confidence intervals are characterized by the property that they hold simultaneously for any value of L_r that might be selected. They are used to determine the particular ranges of L_r over which $\overline{D} = 0$ is rejected. By simply noting the L_r where confidence intervals do not include the value $\overline{D} = 0$ of the dependent variable, the hypothesis may be rejected.

One precaution must be observed when applying the basic statistical method, due to the estimation of the variance σ_D^2 from the standard errors of estimate S_B^2 and S_P^2. A problem arises when the variances of the two regressions are unequal.

The tests of Hypotheses A and B for the difference $\overline{D}$ depend on the variance of the LB_f and LP_f regressions on L_r. Exact tests of hypotheses are applicable assuming the variances of the two regressions are equal.

Approximate tests are applicable when they are unequal. For this study, it may not be assumed, a priori, that the variance in LB_f is necessarily equal to the variance in LP_f. This is because they were obtained from two distinct procedures having different precision. The LB_f was found directly in the field before barrier construction, but LP_f was found indirectly from LA_f, measured after construction, and I_p, computed from the measured traffic variables. The presence of the barrier in the propagation path might introduce a source dependence that would cause the variation in LA_f to be different from the variation in LB_f. The barrier design method has limited information about the traffic source and is, therefore, not assumed precise enough to account for this difference in variation.

The variances of two regressions used in analysis of covariance must first be tested for equality with an F-test. If they can be assumed equal, the common variance may be estimated by pooling the squares of the standard error of estimate for the regressions. The formulas for analysis of covariance between two regressions having equal variance may then be used (Reference 8, Section 14.10). These formulas test Hypothesis A. Formulas to test Hypothesis B with equal variances are based on Reference 7, Section 2 and Reference 5, Chapter 5.

If the F-test on variances for two regressions fails to accept the equality hypothesis, then the formulas to test the Hypothesis A in the analysis of covariance are based on Reference 3, Chapter 34 (3). Hypothesis B for unequal variances is not derived anywhere, but an approximate formula is suggested based on Reference 6 as applied to the equal variance equations.

In the basic model described, the simplest form of linear regression was imposed to relate field levels, LB_f and LP_f, to the source traffic through the control variance L_r in order to 1) imply a statistical rather than a

casual relationship and 2) simplify the model. As to point 1), the statistical relationship between reference and field levels measured simultaneously implies that field levels are correlated to reference levels. It is assumed that for every independently recorded five minute noise sample, the reference and the field levels define a point drawn at random from a bivariate normal distribution of all possible observations (Reference 5, Section 5.3). As to point 2), the traffic variables, TV, are distinct from L_r. They, therefore, could be included in a multiple linear regression model for LB_f and LP_f. However, a given reference level may arise from a distribution of traffic sources having different values of traffic variables. A correlation between reference level and traffic variables would consequently exist. This correlation would tend to defeat the multiple regression, while the model and its assumptions would be more complicated. Rather, it is assumed that the variation in the field level for given reference level is simply due to the distribution of source traffic variables for that reference level. Then just the reference levels may be simply regressed against field levels.

Influence of Traffic Variables

Auxiliary statistical procedures, based on step-wise regression, will be appended to the basic statistical model, in order to qualitatively relate traffic variables to differences between predicted and measured insertion loss. Step-wise regression (Appendix A) is a method which by separating the effects of many independent variables on one dependent variable, determines the significant independent variables. Degree of significance is measured by the amount of reduction in variance of the dependent variable. A multiple regression may be obtained of the dependent variable against the significant independent variables.

Traffic variables can be related directly and indirectly to differences. A direct approach is to step-wise regress field levels versus reference

levels, L_r, and functions of the measured traffic variables. It will be the purpose of step-wise regression then to determine the extent of correlation of field levels with measured traffic variables not explained by L_r. Consider that the correlation between L_r and traffic variables would be stronger than the correlation of field levels and traffic variables because the reference position is much closer to the road than the field position. The strength of the L_r correlation to traffic variables would tend to supercede that of traffic variables with field levels in a step-wise multiple regression when L_r is correlated with field level. This may be particularly true in before barrier construction measurements, where the propagation path attenuation measured by the difference between L_r and LB_f is fairly independent of source traffic variables.

In after construction measurements, the difference between L_r and LP_f may be more strongly influenced by traffic variables, because the barrier has a source dependent attenuation. If a particular barrier design method under test fails to adequately account for source dependence, the difference between L_r and LP_f may be found to be more strongly influenced by traffic variables than that between L_r and LB_f. Note that this procedure applies also the case when no significant correlation is found between field levels and reference levels. In such a case, the field level may vary independently of reference level, making the basic statistical model less sensitive.

The indirect approach to relate traffic variables to differences is to step-wise regress reference levels L_r against functions of the measured traffic variables. The resultant multiple linear regression model may be regarded as describing the source traffic which produces given L_r. By knowing the trend of L_r with respect to average difference, $\bar{D}$, the trend of differences with respect to traffic variables may be seen.

This trend of traffic conditions with respect to differences may provide information to pinpoint deficiencies in the barrier design methods. Where significant differences between predicted and measured insertion loss are found, the corresponding traffic variables can be determined. Since these variables are inputs to the barrier design methods, they may indicate where the design method computations are inaccurate.

IDENTIFICATION OF BARRIER DESIGN METHOD WEAKNESSES

A concomitant objective of the evaluation procedure is to point to weaknesses in design criteria used for barrier design methods. This will be more difficult then the previously explained overall evaluation of insertion loss predictions of a given design method. Insertion loss prediction requires the design method to account for all effects of intervening terrain, barrier, and source. A determination is then made as to whether the design method accurately predicts measured insertion loss. Early in this project, the difference between predicted and measured insertion loss was considered sufficient to evaluate design methods. Later, when the evaluation procedure was developed and the before barrier construction noise surveys (described later in this report) were made, the insertion loss technique was not deemed sufficiently to accurately identify weaknesses.

In order to identify weaknesses it is necessary to resolve measured insertion loss into component attenuations predictable by a given barrier design method. The composite insertion loss will have intervening terrain, barrier, and source components. The most significant component of insertion loss is the barrier attenuation - the attenuation of source noise by the barrier in the absence of ground absorption effects. Included in the barrier attenuation is the attenuation rate characteristic of the source (6 dB per doubling of distance for a point source, 3 dB per doubling of distance for a line source). Since the crux of any barrier design method is the prediction of barrier attenuation from particular design criteria, commonly based on Fresnel number (ratio of twice the path length difference between diffracted and direct rays to the wavelength), it would be desirable to isolate barrier attenuation from the insertion loss as some function of Fresnel Number.

This Fresnel Number will be complicated by the fact that multiple sources on near and far lanes with different path lengths are contributing to the noise. At any rate, a comparison may then be made between predicted and measured barrier attenuation using the foregoing statistical model for insertion loss.

Predicted barrier attenuation is readily obtained from barrier design methods. However, measured barrier attenuation is not readily obtained, because ground absorption and other terrain attenuation components, which tend to reduce measured insertion loss, must be measured and/or estimated. Then they must be added to measured insertion loss in order to arrive at measured barrier attenuation. Ground absorption can be measured to an extent by making two simultaneous measurements at a given field position behind the proposed barrier. One measurement is made at 1.5m (5 ft.) height and the other, at a height above it to eliminate ground effects. The higher position can be anywhere from 4.5m (15 ft.) to 9m (30 ft.) or more above ground, depending on distance from the source. Additional before barrier construction noise measurements, not yet analyzed, were made at the Garden State Parkway, implementing this approach. The difference between the noise levels at the two positions represent ground absorption plus effects due to trees, shrubbery, houses and reflecting surfaces in the propagation path. Changes in the aspect of the roadway are seen at different heights; a higher position sees more of the traffic on a finite multilane roadway both longitudinally and transversely. Attenuations attributable to these effects must be estimated using similar assumptions made by common noise prediction models for barrier design. Before barrier construction reference and field levels will be predicted by the design methods without the barrier for insertion loss prediction; predicted levels may prove helpful in estimating ground absorption when compared against measured levels.

Once stripped of complicating effects, the measured ground absorption may be added to the measured insertion loss to yield measured barrier attenuation, which would then be independent, by definition, of ground effects for a particular site. Let the measured ground absorption be G_m and the measured barrier attenuation be A_m, then with the previously defined measured insertion loss I_m we have:

$$A_m = I_m + G_m \qquad (14)$$

If the barrier design method considered is used to compute barrier attenuation A_p, instead of insertion loss I_p, where A_p ignores ground effects lost from the before barrier situation, then the difference between predicted and measured barrier attenuation, say D'; is:

$$D' = A_p - A_m \qquad (15)$$

From equations (14) and (2) then:

$$D' = A_p - (I_m + G_m)$$

$$D' = A_p - (LB_f - LA_f + G_m) \qquad (16)$$

If two new variables are defined:

$$LP_f' = LA_f + A_p \qquad (17a)$$

$$LB_f' = LB_f + G_m \qquad (17b)$$

where now LP_f' is the after field level increased by the barrier design method attenuation, ignoring ground effects, and LB_f' is the before field level plus ground effects; both measures are directly comparable. The difference D' can be expressed simply as:

$$D' = LP_f' - LB_f' \qquad (18)$$

Equation (18) is in precisely the same form as equation (6) for the difference in predicted and measured insertion loss and the same arguments apply to the estimation of the expected values of the expression:

$$\overline{D}' = \overline{LP_f}' - \overline{LB_f}' \qquad (19)$$

The entire machinery developed for barrier insertion loss can be applied then to barrier attenuation with correspondingly more specific statements made about particular design criteria, within the limitations imposed by the estimation of ground absorption.

In order to more adequately test design criteria, a wide variation in Fresnel number and corresponding barrier attenuation may be achieved by varying frequency and path length difference. A third octave band analysis provides frequency dependent energy content and the resultant third octave L_{eq} reference and field levels may be treated using the same statistical model as for the wide band L_{eq} levels at given positions. Such analysis will be done on the additional before barrier construction noise measurements made at the Garden State Parkway to assist in identifying weaknesses in design methods. A large array of field positions set out at a site would ideally vary path length difference, but significant variation is difficult to achieve because of barrier height and setback from the roadway and proximity of houses, particularly at the Garden State Parkway, at which just two field positions behind the proposed barrier were selected at each site.

The basic evaluation procedure presented in preceeding sections constitutes an analytical tool whereby traffic source variations may be measured and accounted for in the difference between predicted and measured insertion loss. Measurements thus far have been conducted at a particularly favorable location, the Garden State Parkway, from which heavy and medium truck traffic is formally banned. Only incidental medium trucks appear. Source height and emission level differences due to heavy and medium trucks will be eliminated from all these measurements, thereby testing the barrier design criteria for a uniform source, essentially only automobile traffic. At future barrier locations, source height effects on barrier performance will have to be isolated using a calibrated noise source along the roadway, simulating heavy and medium trucks. The nature of the particular noise descriptor L_{10} or L_{eq} may also be sensitive to traffic distribution among automobiles and trucks. Systematic effects can be removed using multiple regressions on traffic variables and information from calibrated noise source experiments. Random effects from random traffic patterns will be estimated in the statistical procedure.

A supplemental calibrated noise source experiment can be designed to vary source height, source position along near and far lanes of the roadway, and receiver position. The calibrated noise source can take the form of a stationary point source, much louder than background levels, placed on the roadway or a calibrated truck moving along the roadway. The experiment would be repeated before and after barrier construction to give measured barrier attenuation as a function of the source height and position (consequently path length difference), which can then be directly compared to predicted attenuation.

FIELD MEASUREMENT PROCEDURES AND RESULTS

The Selection of Sites

As noted previously, shortly after the beginning of Phase I, the Department of Transportation let plans to construct noise barriers along the Garden State Parkway. Therefore, Phase II, the actual measurements of insertion loss and evaluation of design methods, was begun and conducted concurrently with Phase I. The first step was to select the sites at which measurements were to be made. These sites were chosen after taking a variety of factors into consideration.

Six physically separate barriers had been proposed for the Parkway, and it was decided to measure as many as possible, so that the barrier design methods would be tested in a number of different situations. Since barriers are built for the benefit of people, this work must usually be done in residential areas, and it was not always possible to find measurement positions which were both accessible and useable for the experiment. It was necessary to reject on this basis the location of one of the proposed barriers. At all other locations, however, side streets were present which were useable for measurement positions.

In all, seven sites were chosen, six at the locations of the proposed barriers* and one to serve as a control site (explained below). Sites were also selected so that: the barriers measured were different in configuration if possible; there was a minimum of ambient noise at the sites; the traffic noise to be measured emanated primarily from the section of roadway closest to the measurement position (in order to obtain a better correlation between

*Since the start of this project it has been decided that some of the barriers initially planned will not be constructed. A sketch of each site at which measurements were made, as well as its status as of this writing, is included in Appendix C.

reference measurements and field measurements at that position); and the reference position would be free of or far enough from nearby shrubbery to be unaffected by the rustling of leaves.

Unfortunately, the roadway at the locations for which barriers had been proposed was also to undergo alteration, and it was necessary to pick a site as a control site, so that any changes caused in our insertion loss measurement method by these alterations could be monitored and taken into account if found to be significant. The roadway at this site is to be widened by one lane in each direction (which is the alteration to be made at the majority of barrier sites). Since this site serves a specialized purpose, it could be chosen in a non-residential area, thus minimizing the number of measurements lost due to extraneous noise.

Acquisition of the Before Construction Data

Description of Measurements

Measurements were made of noise levels and traffic parameters over five-minute intervals. For convenience the set of all such measurements made in one five-minute period is called an "observation". In addition to the two noise measurements made simultaneously at the reference and field positions, an observation consists of: the number of cars traveling past the microphone in each direction during the period; the number of occasional medium trucks (heavy and medium trucks are formally banned from the Parkway) traveling in each direction; and a measurement of the speed of the vehicles traveling in the three or four lanes nearest the microphones. Also, meteorological measurements (temperature, humidity, wind speed, and wind direction) were taken nominally every half-hour while observations were being made, and an approximate time for each measurement was recorded. All weather data and useable traffic data are recorded in Appendix D.

Instrumentation Used

1) Noise Measurement Equipment - Noise measurements were made using a 1" B&K condenser microphone to measure sound pressure levels at the positions of interest. Each microphone was covered with a polyurethane foam windscreen to reduce the effect of random wind fluctuations. The electrical signal from the microphone was fed directly into a preamplifier, then through a 30.5 m (100 ft.) or 61 m (200 ft.) cable depending on the relative positions of the microphones and field crew. A B&K precision sound level meter A-weighted the signal and amplified it to a level of approximately 2 volts RMS. From the sound level meter, the signal was fed into a instrumentation quality Sony TC 770-4 Tape Recorder, and recorded on Sony professional magnetic tape for later processing.

2) Traffic Volume and Speed Measurement Equipment - The counting of cars and trucks passing the microphone positions was done by hand; an observer for each direction kept a running tally during each five-minute period on a Denominator multiple-tally hand-counter.

The speed of the vehicles traveling in the direction closest to the microphone positions was measured using an Electro-Matic model S-5 radar set. A transmitter-receiver unit near the roadway periodically sends out super high frequency (SHF) radio waves, which are reflected by passing vehicles and picked up by the antenna built into the unit. The reflected waves differ in frequency from the transmitted waves by an amount which depends on the speed of the vehicle the waves were reflected from. The received signal is fed through a cable to the amplifier/power unit, which converts the difference in frequency into a useable signal and outputs that signal to a meter, calibrated in miles-per-hour. An Esterline-Angus chart recorder, also calibrated in miles-per-hour and connected to an auxiliary output from the amplifier, made a permanent record of the speeds measured.

3) Temperature, Humidity and Wind Measurement Equipment - Temperature and humidity were measured with a Bendix psychrometer, an apparatus which forces ambient air past wet- and dry-bulb thermometers to give readings which when compared yield the ambient humidity. Temperature readings were also taken on this device, before humidity measurements were made.

Wind speed and direction measurements were made with a Belfort Instrument wind measurement set. This is a hand-held instrument which consists of two parts: 1) A set of parallel vanes connected to a pointer which revolves around a scale from which wind direction can be read, and 2) a small slotted rotating cylinder which drives an electrical generator, the output of which is measured on a scale calibrated in knots/hr built into the instrument.

4) Time Measurement Equipment - A Minerva stopwatch was used both for the time of day and to control the length of the measurement periods.

Method of Taking Before Construction Measurements

1) Instrumentation Set-Up - In order to fulfill the requirements of the project, it was necessary to follow a rather fixed procedure when taking the data. To insure that the position at which reference measurements were made would be unaffected by the barrier, at each site the reference microphone was placed at a position which would be 1.5 m (5 ft.) above, and directly over the proposed barrier. (The height of the barrier at each site is given in Appendix C.) This height was attained by mounting the microphone and preamplifier on a section of antenna mast, which was in turn mounted on a television camera tripod. This position was ascertained to be completely independent of the shadow of the barrier, any reflections from the barrier, and any sound wave "edge effects" created by the barrier (see for example Reference 4 and Reference 9 p. 5-17). The field microphone position in each case was either 15.2 m (50 ft.)

or 30.5 m (100 ft.) further from the roadway than the reference position, as measured on a line perpendicular to the roadway and through the field position in question. (That is, if this line also passed through the reference position; if not, it was parallel to the line perpendicular to the roadway and through the reference position (see sketches of sites in Appendix C).) These microphone positions are denoted position 1 and position 2, respectively. The height of the field microphones was approximately ear level (1.5 m, or 5 ft.) in each case.

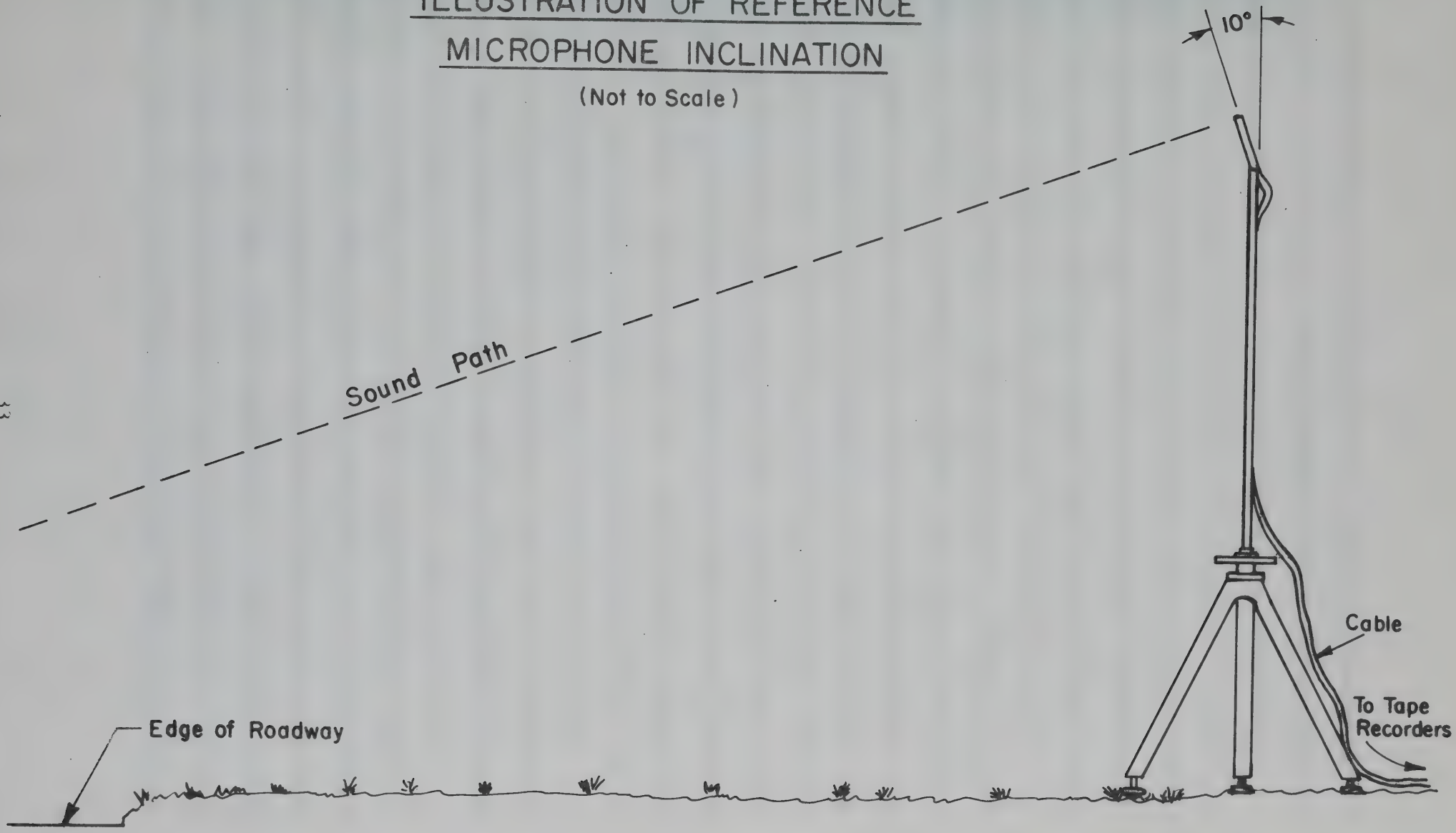
The reference microphone, in addition to being raised to the specified height, was tilted at an angle of approximately 10 degrees towards the roadway, instead of being vertically mounted (see Figure 3). This was done so that sound from the roadway would impinge upon the microphone in a manner consistent with the design of the microphone. The microphone was aimed toward the roadway with a small siting telescope positioned along the perpendicular to the roadway through the reference position.

The taking of speed data initially presented a problem in that the graphs obtained by aiming the radar toward the traffic was virtually unanalyzable - the parkway was usually so heavily traveled that the radar continuously read between 80 and 115 km/hr (50 and 71 mph) rather than showing the speeds of individual vehicles. To ameliorate this problem the radar was aimed at an angle to the roadway, so that it was possible for an individual vehicle to pass completely through the radar beam before another entered it. This did not solve the problem completely, since cars often passed in groups, but it did yield a graph to which individual speeds could be assigned. Since the radar actually measures the component of the speed of an object which is directed toward the radar, a series of pass-by tests were later performed at several speeds in order to determine the correction which must be made to obtain the true speed

Figure 3

ILLUSTRATION OF REFERENCE MICROPHONE INCLINATION

(Not to Scale)



of vehicles on the roadway. By this procedure an estimate for the speed of traffic at each site was obtained.

Finally, the siting telescope used to aim the reference microphone was moved to a convenient position and aligned towards true north (11 degrees west of magnetic north, for 1976, at the locations being considered) by a compass mounted on the instrument. Wind direction measurements were then obtained by aiming the wind measurement set in the direction of the telescope.

2) Taking of Before Construction Data - When the equipment had been set up, and at the beginning of each reel of recording tape after that, the microphones and recording systems were calibrated using a B&K pistonphone, which produces a constant sound signal of known intensity (124 dB). This is recorded on the tape, and the level of all data taken subsequently is determined with respect to this signal. As a check to insure that the system had not changed throughout the hour that each tape lasted, the pistonphone was again placed on the microphone and re-recorded at the end of each tape. By comparing this signal with the original, any changes which might have occurred in the system, thereby affecting the data taken, could be detected.

The radar chart recorder was also calibrated (once at the beginning of each day), by holding tuning forks made for this purpose in front of the transmitter-receiver, and adjusting the pen of the graph to read accordingly.

After calibration, a series of five-minute observations were begun, and continued until approximately mid-afternoon. Two or three hours of data were taken each day. Each five-minute observation required a coordination of the taking of all necessary information (noise measurements at each position, a count of cars and trucks in each direction, and speed data). This was accomplished by assigning one man to operate the tape recorders, one man to monitor the radar and count traffic in one direction, one man to count traffic

in the other direction and record both counts at the end of each observation, and if available, a fourth man to serve as timekeeper and to take the weather measurements. The typical sequence of events in the taking of observations follows.

After receiving a "ready" from each man, the timekeeper gave the "start" command, and started the stopwatch. The man operating the tape recorders would simultaneously begin recording noise levels from both the reference and field positions, and the others would begin counting traffic. In addition, the man counting traffic in the direction nearest the microphone positions started the radar chart recorder. During the five-minute period of taping, the man operating the tape recorders would note the time, and any extraneous noise heard during the observation which might affect the levels measured. At four minutes, thirty seconds a "thirty seconds" warning was given by the timekeeper, and when five minutes had elapsed the "stop" command followed. At this point the man counting the closer traffic stopped the chart recorder, forwarded it to separate the record just made from the next, and identified the upcoming graph by writing in its observation number. The man counting traffic in the opposite direction recorded the car and truck counts for both directions. Each man then reset his hand counter, and signaled "ready" to the timekeeper.

The tape was allowed to run for an extra ten or fifteen seconds (to insure that the observation was not inadvertently cut short), then the man operating the recorders voice-recorded "end of observation" and identified the upcoming observation by number and time. When this was done, he also signaled "ready" to the timekeeper. When the timekeeper had received a ready signal from each man, he again started the watch, gave the command "start",and the cycle repeated.

The recording heads and tape guides of the tape recorders were normally checked and cleaned twice during each hour of taping, to prevent iron oxide

build-up from the magnetic tape from reducing the quality of the recording. Also, the timekeeper every half-hour recorded the temperature, humidity, and wind speed and direction.

If a fourth man was not available, the taking of weather measurements fell to the man operating the recorders, and the timekeeping responsibilities fell to anyone with a free hand.

Processing of the Data: Instrumentation, Discussion

Temperature, wind speed and direction, and traffic counts were recorded in the form in which they were to be used, and thus required no additional processing. Humidity measurements required only the conversion of the wet- and dry-bulb readings into a figure representing the relative humidity. Speed and noise measurements, however, required more extensive processing.

The radar turned out to be a relatively uncooperative piece of equipment, and it spent a large percentage of the time that observations were being taken in the repair shop. Thus, unfortunately, no speed data exists for many observations. The speed data which were taken were processed by taking the peak reading for each portion of the graph between successive readings of 8 km/hr (5 mph) or less. As pointed out before, these portions often represented more than one vehicle; however, it was felt that the average of the peaks of each portion would be representative of the speed of vehicles on the parkway, and therefore this is the estimate which was used. It was found that the correction factor necessary to adjust for the angle of the radar to the roadway was essentially linear with speed, so that it was possible to apply the correction to the average obtained above rather than to each individual peak before averaging. The standard deviation of the peaks was also computed (for the corrected average), as an indication of the speed variation.

The A-weighted noise data taken was played back on the Sony recorders into a B&K Graphic Level Recorder, which made a graph of noise intensity (in dBA) versus time. While the graph was being made, electrical signals corresponding to the position of the pen on the Graphic Level Recorder were fed into a B&K Statistical Distribution Analyzer, which essentially takes a position reading of the pen every tenth second and registers it on a counter corresponding to a 5dB interval. In this manner the data was put into digital form.

Throughout the taking and processing of the data, precautions were taken to insure that extraneous noise which might affect the results were screened from the data. In the field, any observation which was obviously influenced by non-roadway noise was halted and voided; and as stated previously, questionable observations were noted. In the laboratory, the recorded noise was monitored and the notes of extraneous noise made in the field were checked during the playback. Afterward, the graphs of the reference and field positions for each observation were checked, as were calibration signals at the beginning and end of each tape, for discrepancies large enough to affect the figures obtained for the individual observations. The number of observations lost due to aircraft fly over, residential noise, and equipment or measurement error was typically rather high, usually in the neighborhood of 50 to 60%.

The digitized noise data from noise observations which were free of extraneous noise were computer-coded, and the L_{eq}, L_{10}, L_{50}, L_{90} and standard deviation for each calculated. **L_{10} and L_{eq} are presented in tabular form in Appendix D.**

Two major errors were discovered during the project which will affect our results. Near the end of the taking of data, it was discovered by the field crew

that the pistonphone, which provided the calibration signal, had sometimes been incorrectly mounted on the microphone, which had the effect of lessening the intensity of the signal applied. In the laboratory it was determined that the maximum error that this condition might cause is 1.0 dBA, and it is likely that some of the observations contain an error of this size. Unfortunately, there is no way to detect which or how many of the observations contain this error.

The second error was due to a difference in the frequency response of the tape recorders as a result of head wear and misalignment. The error introduced in each observation by this factor is estimated to be on the order of 0.6 dBA.

Results

The data collected thus far are provided in Appendix D in two sections: noise measurement data and weather data.

In the first section, observations are listed by observation number under the appropriate location and field position*. As mentioned previously (under "Description of Measurements"), each observation consists of a measurement of traffic noise at both the reference and field positions, a count of cars traveling in each direction, a count of trucks traveling in each direction, and a measurement of the speed of vehicles in the three or four lanes nearest the microphones. The measurement period was five minutes long for each observation.

Only those observations which were judged acceptable in the processing outlined in the previous section are listed. The noise levels measured at each position were calculated in terms of both L_{10} and L_{eq} for later comparison with the various design methods to be tested. In addition to the speed data presented, the standard deviation of the speeds obtained from the graphs is given as an

*These positions are graphically presented in Appendix C.

indication of the variation in vehicle speeds over the five-minute measurement period.

An in-depth analysis has not yet been done on the data obtained, so only limited statements can be made about the data at this point. In general, for a particular location and field position there was a small variation in noise levels at the reference position, and a somewhat larger variation at the field position, although there are several exceptions to this trend. Some of the speeds obtained (Sunset Drive, Position No. 2; Control Site, Position No.2) are usually high, and it is difficult to find an explanation for this phenomenon. It is likely that our method of deriving speeds from the radar graphs would yield slightly higher numbers for heavy traffic, since only one speed recorded (the highest)for each group of cars is used in the calculations, and heavier traffic would produce fewer and larger groups. However, it is difficult to see how this could account for an error of more than 3 or 4 mph. The radar is assumed to have been working correctly, since it was calibrated at the beginning of each day, and when it malfunctioned it either did not work at all, or read a constant 140 mph. The speed graphs obtained for these observations were checked, and some were reprocessed and the speeds recalculated. No error was found in this part of the processing. The only remaining possibilities are that the radar was set up incorrectly, or that the traffic actually was traveling at or near the speeds indicated on the days these observations were made. A final check of the field records for those days indicate that the radar was set at the same angle used throughout the taking of data for the project. Therefore, although the data does arouse suspicion, we have no basis on which to disregard it, especially since it is known that traffic does occassionally reach rather high speeds on the parkway.

The second section of Appendix D contains weather data, which is also listed by location and field position. The "Direction of Near Traffic at Measurement Site" is the direction in which the traffic nearest the measurement positions is traveling. The headings are self-explanatory, with the possible exception of "Corresponding Observations" -- these are the observations which are nearest in time to the listed weather data. Observations which correspond to two sets of weather data fall halfway between the two in time. Wind speed was measured in knots and is, therefore, recorded in these units. Conversion factors and additional information appear in footnotes at the bottom of each page. Anomalous readings and uncertain information are accompanied by question marks.

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This manual outlines the theory behind and the use of the statistical program package for the NJDOT IBM 370/145 MOD 3 computer. Step-wise regression in particular is available in the package.

Barriers Sound

Berenak, L., and Kurze, M., "Chap. 7: Sound Propagation Outdoors", Noise and Vibration Control, McGraw-Hill, Inc., New York, 1971.

This chapter breaks down into components the attenuation outdoor sound is subject to, and provides a summary of the present state of knowledge concerning each component.

Commins, D.E., Kugler, B.A. and Piersol, A.G., "Evaluation of Highway Noise Propagation Based upon Mean Energy Levels." Proceedings of the National Conference on Noise Control Engineering (Noise - Con 73). pp. 115-120, 1973.

This paper presents the results obtained from an experiment which measured traffic noise over different ground coverings, at different heights, and at different distances from the roadway. L_{01}, L_{10}, L_{50}, L_{90}, and L_{eq} were compared, and a "linear propagation loss factor" was found for each by performing linear regressions on the data.

Delany, M., "Noise Research at the National Physical Laboratory with Particular Reference to Road traffic", Proceedings of the International Conference on Noise Control Engineering (Inter-Noise 72), pp. 195-199, 1972.

This paper describes one of several studies at the National Physical Laboratory in England aimed at prediction of traffic noise levels in varying physical situations.

Donovan, J., and Ketcham, T., "Transportation Noise - Its Measurement and Evaluation "Sound and Vibration, 7 (10), p. 4ff, October 1973.

This article presents a brief review of two major community noise problems - aircraft and traffic noise - and outlines test procedures and equipment available for the measurement of noise from these sources.

Fisk, D., "Attenuation of L_{10} by Long Barriers "Journal of Sound and Vibration , 38 (3), pp. 305-316, 1975.

This article examines the theoretical concepts underlying the construction of curves for the attenuation of L_{10} by barriers, and more detailed calculations, resulting in new curves, are made.

Gordon, C., Galloway, W., Kugler, B., and Nelson, D., Highway Noise - A Design Guide for Highway Engineers, NCHRP Report 117, 1971.

This report documents an empirically derived procedure to predict traffic noise. Barrier attenuation computations are based on a version of Maekawa's method.

Jonasson, H., "Sound Reduction by Barriers on the Ground ", Journal of Sound and Vibration, 22 (1) pp. 113-126, 1972.

This paper investigates the effect of the ground and the effect of a noise barrier on sound propagation by comparing calculated and measured values of noise attenuation at various frequencies.

Kugler, B., and Piersol, A., Highway Noise - A Field Evaluation of Traffic Noise Reduction Measures, NCHRP Report 144, 1973.

This report documents the evaluation and modification of noise control prediction procedures outlined in NCHRP Report 117. In particular, a modified barrier attenuation computation procedure is presented.

Kurze, M., "Noise Reduction by Barriers", Journal of the Acoustical Society of America, 55 (3) pp. 504-518, March 1974.

This is a review of current literature which thoroughly summarizes the present state of knowledge in practically all areas of barrier acoustics.

Maekawa, Z., "Noise Reduction by Screens", Applied Acoustics, 1 (3) pp. 157-173, 1968.

This paper presents barrier attenuation data the author has obtained, as well as a method for calculating the attenuation which can be expected from a barrier.

Parkin, P., and Scholes, W., "The Horizontal Propagation of Sound from a Jet Engine Close to the Ground, at Hatfield", Journal of Sound and Vibration, 2 (4), pp. 353-374, 1965.

This paper describes the continuation of a previous experiment (see following reference), to determine whether the previous results were dependent on the particular site chosen, and to measure the effect of temperature inversions.

Parkin, P., and Scholes, W., "The Horizontal Propagation of Sound from a Jet Engine Close to the Ground, at Radlett ", Journal of Sound and Vibration 1 (1), pp. 1-13, 1964.

This paper describes an experiment designed to discover the main factors (found to be wind and ground effect) affecting the propagation of noise from sources close to the ground to receivers close to the ground.

Peterson, A., and Gross, E., Handbook of Noise Measurement, General Radio Company; Concord, Massachusetts, 1972.

This book presents the basic concepts underlying noise perception and noise measurements.

Scholes, W., and Vulkan, G., "A Note on the Objective Measurement of Road Traffic Noise", Applied Acoustics, 2 (3), pp. 185-197, July 1969.

This article discusses some of the techniques which are currently being used by experimenters to measure traffic noise.

Scholes, W., "Traffic Noise Criteria" Applied Acoustics, Vol. 3, p. 1-21, 1970.

This article is a discussion of two important units by which annoyance from traffic noise are measured: Traffic Noise Index and Mean Energy Levels.

Scholes, W., Salvidge, A., and Sargent, J., "Field Performance of a Noise Barrier", Journal of Sound and Vibration, Vol. 16, pp. 627-642, 1971.

This paper discusses experiments carried out by the author, in which measurements of the performance of noise barriers were made over a range of heights and wind conditions.

Scholes, W., Salvidge, A., and Sargent, J., "Motorway Noise Propagation and Screening", Journal of Sound and Vibration, 38 (3) , pp. 281-303, 1975.

This article describes a study in which measurements of traffic noise, both shielded and unshielded, are made and compared with levels predicted by certain prediction methods. The effects of other parameters on traffic noise such as traffic volume, traffic speed, and wind, are also investigated.

Sharp, B., "The Measurement of Noise from Motor Vehicles on the Highway", Proceedings of The International Conference on Noise Control Engineering (Inter-Noise 72), pp. 220-224, 1972.

This paper investigates factors which influence the measurement of traffic noise, and the degree of the effect of each.

_____, Fundamentals and Abatement of Highway Traffic Noise, U.S. Department of Transportation Report No. FHWA-HHI-HEV-73-7976-1, June 1973.

This is a textbook prepared under the direction of the Federal Highway Administration. It covers (by chapter) the fundamentals of sound, traffic noise sources, environmental noise measurements, traffic noise prediction, and noise abatement.

APPENDIX A

Short Introduction to Regression Analysis

Linear Regression

If a measured quantity, which is influenced by any number of observed effects, varies so that its average value bears a linear or approximately linear relationship to some other measured quantity or quantities, then that relationship can be estimated by carrying out a linear regression analysis of the first quantity on the others. This procedure mathematically fits a straight line (the estimated regression line) to the graph of a relatively small number (that is, a sample) of observations of the quantities under consideration- the first (dependent) quantity plotted against the other (independent) quantities. If the relationship of the quantities is known to be linear, and if the quantities measured meet certain other requirements, then a statement specifying the accuracy of the estimated relationship may be made.

Consider as an example the situation described in the body of this report: taking pairs of simultaneous noise measurements at two locations near a roadway, one position serving as a reference position, the other being the field position. If it is known that the average noise level at the field position increases as a linear function of the noise level at the reference position (that is, if the average noise level at the field position for any given level at the reference position is always equal to a constant multiple of the level at the reference position plus a second constant), then one may estimate that relationship by taking a small number of pairs of simultaneous measurements at each position and performing a regression analysis of the noise levels measured at the field position on those measured at the reference position. The estimation obtained (the estimated regression line) can be used in a number of ways - for instance, it could be used to estimate the true average noise level at the field position

for some particular noise level at the reference position. If, in this example, it is also known that the corresponding noise levels measured at the two positions meet certain other statistical requirements (the standard deviation of the field noise levels for a given reference noise level is constant over all reference noise levels measured; the distribution of the field noise levels for each reference noise level is normal), then, based on the regression, for each reference noise level it is possible to make a statement such as "the probability is p (e.g. 95%) that the actual value of the average field noise level for the reference noise level specified lies within d (e.g. 1.5) decibels of the estimated value." - where p is chosen arbitrarily and d depends on p and the number of simultaneous (paired) measurements taken at the two positions.

A multiple linear regression is simply an extension of the linear regression described in the example above - the difference being that the relationship of one dependent variable to several other independent variables, instead of only one, is estimated. As in the two variable case, the accuracy of the estimation can be specified, provided that the quantities measured meet the necessary requriements.

Step-wise Regression (see Reference 10)

Step-wise regression, as used in this report, is a computer technique which isolates certain variables of a given set, depending upon the relationship each variable bears to some other designated variable. Essentially, the computer measures to what extent each variable in the set accounts for the variation in the designated variable, and selects the variable which accounts for the greatest amount. The computation is then repeated for the remaining variables, but only on that variation of the designated variable which is not

accounted for by the first variable selected. A second variable is selected which explains the greatest amount of the remaining variation, and the computation is again repeated for the variation which remains after both the first and second variables have been considered. The process continues until the selected variables no longer explain a statistically significant amount of the remaining variation.

APPENDIX B

Procedure for Evaluating Barrier Design Methods

The steps to be followed in analyzing the barrier design models from before and after barrier construction insertion loss measurement are flowcharted in Figure B3. The measured noise data consist of two independent samples of field levels, L_f, reference levels, L_r, and traffic variables, TV, obtained before and after barrier construction. The data for one site may be represented like so:

Before: $(LB_{fi}, L_{ri}, TV_{ji})$

$i = 1,2,...,N_B$ observations
$j = 1,2,...,k$ traffic variables

After: $(LA_{fi}, L_{ri}, TV_{ji})$

$i = 1,2,...,N_A$ observations
$j = 1,2,...,k$ traffic variables

where N_B is not necessarily equal to N_A.

Given S sites and P barrier design methods, the same steps in the flowchart may be followed for each site for all barrier design methods in turn. The result is two loops in the flowchart, the first being the "site loop", the second, the "barrier design method loop" nested in the site loop.

Enter the site loop in the flowchart to start the process. Consider one of the sites. Now determine the relationship between traffic variables and reference levels at the site. First pool all before and after reference levels and traffic variables data to obtain a pooled sample of $N_B + N_A$ observations:

Pooled: (L_{ri}, TV_{ji})

$i = 1,2,\ldots,N_B + N_A$ observations
$j = 1,2,\ldots,k$ traffic variables

The pooling is permitted because we assume the reference levels are unaffected by the presence of the barrier after construction.

Next perform a step-wise regression with L_r as the dependent variable and functions of traffic variables (e.g. 10 log TV_j) as independent variables. A multiple linear regression will be produced to be later used to qualitatively relate differences between predicted and measured barrier insertion loss to traffic variables through reference levels.

Also separately step-wise regress before and after field levels, LB_f and LA_f, against corresponding reference levels and functions of traffic variables. These regressions will indicate the degree of correlation between field levels and reference levels, primarily; and the influence of traffic variables in the presence of reference levels, secondarily. If L_r is not significantly correlated with either LB_f or LA_f, the particular field level may be assumed to fluctuate independently of L_r with changes in source traffic.

In order to obtain the simple linear regressions of field levels versus reference levels used in the basic statistical model, linearly regress LB_f and LA_f on L_r. Thus, estimates of expected values, designated by a caret ($\wedge$), of $\overline{LB_f}$ and $\overline{LA_f}$, the true population averages, at particular L_r are obtained:

$$\widehat{LB}_f = \hat{\beta}_B L_r + \hat{\alpha}_B \qquad (1a)$$

$$\widehat{LA}_f = \hat{\beta}_A L_r + \hat{\alpha}_A \qquad (1b)$$

Here the values of $\widehat{LB}_f$, $\widehat{LA}_f$, $\hat{\beta}_B$, $\hat{\alpha}_B$, $\hat{\beta}_A$, and $\hat{\alpha}_A$ are respectively estimates of the true population averages, $\overline{LB}_f$, $\overline{LA}_f$, with true slopes and intercepts, β_B, α_B, β_A, α_A.

Now we enter the barrier design method loop in the flowchart. Choose one of the barrier design methods, say BDM. Then for each set of measured traffic variables, TV_1, TV_2, ..., TV_k, measured <u>after</u> barrier construction, predict the insertion loss, A_p, from the design method. Thus if I_p is a function of TV we can write:

$$I_{pi} = BDM(TV_{1i}, TV_{2i}, \ldots, TV_{ki}) \qquad (2)$$
$$i = 1,2,\ldots,N_A \text{ observations}$$

From A_p, form the predicted field level before construction of the barrier, LP_f, for the set of after construction noise samples:

$$LP_{fi} = LA_{fi} + I_{pi} \qquad (3)$$
$$i = 1,2,\ldots,N_A \text{ observations}$$

The after construction noise sample now appears like so:

After: $(LP_{fi}, L_{ri}, TV_{ji})$

$i = 1,2,\ldots,N_A$ observations
$j = 1,2,\ldots,k$ traffic variables

Step-wise regress LP_f against L_r and traffic variables. Interpret the results as before, for LB_f and LA_f. Then using only L_r as the independent variable, linearly regress LP_f on L_r to get:

$$\widehat{LP}_f = \hat{\beta}_p L_r + \hat{\alpha}_p \qquad (4)$$

Here $\hat{\overline{LP}}_f$, $\hat{\beta}_p$, and $\hat{\alpha}_p$ are estimates of the true population average, $\overline{LP}_f$, with true slope and intercept, β_p, α_p.

The basic statistical model (covariance analysis) may now be used to determine if the true average difference, $\overline{D}$, between predicted and measured insertion loss is zero. The difference $\overline{D}$ is expressed as the difference between the true regressions of LP_f and LB_f:

$$\overline{D} = \overline{LP}_f - \overline{LB}_f$$

or

$$\overline{D} = (\beta_p - \beta_B)L_r + (\alpha_p - \alpha_B) \qquad (5)$$

Estimates, $\hat{D}$, of the true differences are obtained from the regressions based on before and after samples:

$$\hat{D} = (\hat{\beta}_p - \hat{\beta}_B)L_r + (\hat{\alpha}_p - \hat{\alpha}_B) \qquad (6)$$

The next block of steps incorporate formulas to test the Hypothesis A: $\overline{D} = 0$ for all L_r and Hypothesis B: $\overline{D} = 0$ for particular L_r from these estimates (subsection entitled "Statistical Model" in the report). As noted before, however, a problem arises in that exact equations exist only for the case in which the variances of the two regressions are equal. Otherwise, only approximate formulas are available. Since it has been asserted that equal variances cannot be a priori assumed, an F-test for equality of variances using the standard errors of estimate will be performed.

Two conditions will be imposed before the null hypothesis of equal regression variances is accepted in the procedure. First, the F-test will be conducted at the 5% level of significance. If the null hypothesis is rejected as indicated in this decision block in the flowchart, unequal variances (worst case) will be assumed. If the null hypothesis fails to be rejected, it will

not yet be accepted unless the power of the F-test used meets a minimum level, say 50%. This test insures the variance of the difference between the regressions may be estimated by pooled estimates of the variances of the two regressions. The next decision block indicates acceptance or non-acceptance of the null hypothesis based on this power criterion.

By way of explanation, the power of the F-test is the probability of rejecting the null hypothesis when an alternative hypothesis is actually true. Thus if the power is greater than or equal to 50%, the chances of rejecting a false null hypothesis are better than one in two. Since the F-test is generally regarded to be fairly sensitive to differences in the variances tested under the assumption of normality, this arbitrary figure of 50% may be considered sufficient power.

The test of equality of variance is performed using estimates for the variance found from the standard errors of estimate of the LP_f and LB_f regressions, S_P and S_B, with $N_A - 2$ and $N_B - 2$ degrees of freedom, respectively (Reference 2, Section 8-2). Form the F statistic as follows:

$$F(f_P, f_B) = \frac{S_P^2}{S_B^2} \tag{7a}$$

where standard errors of estimate are given by

$$S_P^2 = \frac{SSy_P - \beta_P^2 SSx_A}{N_A - 2} \tag{7b}$$

with $f_P = N_A - 2$ degrees of freedom

$$S_B^2 = \frac{SSy_B - \beta_P^2 SSx_B}{N_B - 2} \tag{7c}$$

with $f_B = N_A - 2$ degrees of freedom.

Sums of squares in the above are:

$$SSy_P = \sum(LP_{fi})^2 - (\sum LP_{fi})^2/N_A \qquad (7d)$$

$$SSx_A = \sum(L_{ri})^2 - (\sum L_{ri})^2/N_A \qquad (7e)$$

$$i = 1,2,\ldots,N_A$$

$$SSy_B = \sum(LB_j)^2 - (\sum LB_j)^2/N_B \qquad (7f)$$

$$SSx_B = \sum(L_{rj})^2 - (\sum L_{rj})^2/N_B \qquad (7g)$$

$$j = 1,2,\ldots,N_B$$

The critical values of the F distribution, determined from tables (Reference 2) for f_P and f_B degrees of freedom, in a two tailed test at the 5% level of significance, are $F_{.025}(f_P,f_B)$ and $F_{.975}(f_P,f_B)$. The equal variance hypothesis is rejected if $F(f_P,f_B)$ is greater than $F_{.975}(f_P,f_B)$ or less than $F_{.025}(f_P,f_B)$. Otherwise, the null hypothesis will fail to be rejected and the power of the F-test determined by the following procedure. Consider an alternative hypothesis that the true variances σ_P^2 and σ_B^2 are in the ratio R, a value to be determined in Phase II, where R is greater than unity. That is,

$$R = \frac{\sigma_P^2}{\sigma_B^2} > 1 \qquad (8)$$

Then evaluate new critical limits for rejecting this hypothesis when it is true, thus:

$$F'_{lower} = \frac{1}{R} F_{.025}(f_P,f_B) \qquad (9a)$$

$$F'_{upper} = \frac{1}{R} F_{.975}(f_P,f_B) \qquad (9b)$$

Refer to F statistic tables to determine the lower and upper percentiles of the F distribution associated with F'_{lower} and F'_{upper}, respectively. The power of the F-test is then just unity minus the difference of the upper and lower percentiles. If the power is greater than or equal to 50%, the null hypothesis of equal variance is accepted. Otherwise, the variances are worst-case assumed unequal. Depending on the outcome of the decision blocks concerning the equality of variances, use the appropriate formulas below to test Hypotheses A and B.

Covariance Analysis - Hypothesis A Formulas

The general hypothesis on differences between predicted and measured insertion loss, $\bar{D} = 0$ for all L_r, is tested by testing equality of slopes $\beta_P - \beta_B = 0$, and intercepts, $\alpha_P - \alpha_B = 0$, of the LP_f and LB_f regressions on L_r using t-tests. The formulas assuming equality of variances of the regressions are taken from Reference 8, Section 14.10. Those assuming unequal variances are based on the appropriate discussion in Reference 3, Chapter 34(3).

Equality of Slopes

For equal variances

$$t^{\beta}(f) = \frac{\hat{\beta}_P - \hat{\beta}_B}{S_D\sqrt{\frac{1}{SSx_A} + \frac{1}{SSx_B}}} \qquad (10a)$$

where the variance of the difference in the two regressions is estimated by the pooled standard errors of estimate of each regression given by:

$$S_D^2 = \frac{(N_A - 2)S_P^2 + (N_B - 2)S_B^2}{N_A + N_B - 4} \qquad (10b)$$

with degrees of freedom given by:

$$f = N_A + N_B - 4 \tag{10c}$$

The sums of squares SSx_A and SSx_B have been previously defined.

Equality of Slopes

For unequal variances

$$t^{\beta}(f') = \frac{\hat{\beta}_P - \hat{\beta}_B}{\sqrt{\frac{S_P^2}{SSx_A} + \frac{S_B^2}{SSx_B}}} \tag{10d}$$

with approximate degrees of freedom given by:

$$f' = \frac{\left(S_P^2/SSx_A + S_B^2/SSx_B\right)^2}{\frac{\left(S_P^2/SSx_A\right)^2}{N_A - 2} + \frac{\left(S_B^2/SSx_B\right)^2}{N_B - 2}} \tag{10e}$$

Equality of Intercepts

For equal variances

$$t^{\alpha}(f) = \frac{\hat{\alpha}_P - \hat{\alpha}_B}{S_D \sqrt{\frac{\sum(L_{ri})^2}{N_A SSx_A} + \frac{\sum(L_{rj})^2}{N_B SSx_B}}} \tag{11a}$$

where $i = 1,2,\ldots,N_A$ and $j = 1,2,\ldots,N_B$

$$f = N_A + N_B - 4 \tag{11b}$$

Equality of Intercepts

For unequal variances*

*This formula is not found in Reference 3. It is an extension of the formula for slopes to intercepts.

$$t^{\alpha}(f') = \frac{\hat{\alpha}_P - \hat{\alpha}_B}{\sqrt{\frac{S_P^2\sum(L_{ri})^2}{N_A SSx_A} + \frac{S_B^2\sum(L_{rj})^2}{N_B SSx_B}}} \qquad (11c)$$

where $i = 1,2,\ldots,N_A$ and $j = 1,2,\ldots,N_B$

$$f' = \frac{\left[\frac{S_P^2\sum(L_{ri})^2}{N_A SSx_A} + \frac{S_B^2\sum(L_{rj})^2}{N_B SSx_B}\right]^2}{\frac{\left[\frac{S_P^2\sum(L_{ri})^2}{N_A SSx_A}\right]^2}{N_A - 2} + \frac{\left[\frac{S_B^2\sum(L_{rj})^2}{N_B SSx_B}\right]^2}{N_B - 2}} \qquad (11d)$$

Covariance Analysis - Hypothesis B Formulas

The specific difference between predicted and measured insertion loss, $\overline{D} = \overline{LP}_f - \overline{LB}_f$ for given L_r, estimated from the difference in regressions, $\hat{D}(L_r) = \hat{LP}_f - \hat{LB}_f$, has confidence limits depending on F distribution critical values of the form:

$$\overline{D} \text{ between } \hat{D}(L_r) \pm \sqrt{2F}\, g(L_r) \qquad (12)$$

Where $g(L_r)$ is a function of reference level, as is $\hat{D}(L_r)$. These confidence limits were derived exactly for equal variances of the two regressions based on Reference 7, Section 2 and Reference 5, Chapter 5. They were not able to be derived exactly for unequal variances, but may have an approximate form similar to that for the equal variance case. Hypothesis B will be rejected if the value $\overline{D} = 0$ lies outside these confidence limits for specific L_r levels. Otherwise the hypothesis will fail to be rejected, but still not accepted, for other L_r levels. The formulas are:

For equal variances

$$\bar{D} \text{ between } \hat{D}(L_r) + \sqrt{2F_{.95}(2,f)}\, S_D \sqrt{\frac{1}{N_A} + \frac{(L_r-\bar{L}_{rA})^2}{SSx_P} + \frac{1}{N_B} + \frac{(L_r-\bar{L}_{rB})^2}{SSx_B}} \qquad (13a)$$

where

$$\hat{D}(L_r) = (\hat{\beta}_P-\hat{\beta}_P)L_r + (\hat{\alpha}_P-\hat{\alpha}_B) \qquad (13b)$$

$$\bar{L}_{rA} = \frac{\sum L_{ri}}{N_A}, \quad i = 1,2,\ldots,N_A \qquad (13c)$$

$$\bar{L}_{rB} = \frac{\sum L_{ri}}{N_A}, \quad i = 1,2,\ldots,N_B \qquad (13d)$$

S_D and f are the pooled standard error of estimate and pooled degrees of freedom defined in equations (10b) and (10c). Other quantities were defined in equations (7). $F_{.95}(2,f)$ is the critical value of the F distribution at the 5% level of significance with two and f degrees of freedom.

For unequal variances

$$\bar{D} \text{ between } \hat{D}(L_r) + \sqrt{2F_{.95}(2,f')} \sqrt{S_P^2\left[\frac{1}{N_A} + \frac{(L_r-\bar{L}_{rA})^2}{SSx_A}\right] + S_B^2\left[\frac{1}{N_B} + \frac{(L_r-\bar{L}_{rB})^2}{SSx_B}\right]} \qquad (13e)$$

$F_{.95}(2,f')$ is the critical value of the F distribution at the 5% level of significance with 2 and f' degrees of freedom. The value of f' is problematical. A worst case estimate is to use the minimum value of the degrees of freedom associated with the standard errors of estimate of the two regressions, that is, either $f_P = N_A-2$ or $f_B = N_B-2$. A more optimistic value may be inferred from Reference 6. This estimate is formed by the weighted sum of mean squares like so:

$$f' = \frac{\left\langle S_P^2\left[\frac{1}{N_A} + \frac{(L_r-\bar{L}_{rA})^2}{SSx_A}\right] + S_B^2\left[\frac{1}{N_B} + \frac{(L_r-\bar{L}_{rB})^2}{SSx_B}\right]\right\rangle^2}{\frac{\left\langle S_P^2\left[\frac{1}{N_A} + \frac{(L_r-\bar{L}_{rA})^2}{SSx_A}\right]\right\rangle^2}{N_A-2} + \frac{\left\langle S_B^2\left[\frac{1}{N_B} + \frac{(L_r-\bar{L}_{rB})^2}{SSx_B}\right]\right\rangle^2}{N_B-2}} \qquad (13f)$$

However, the difference between the estimates of f' is slight, probably affecting the size of the confidence limits on the order of tenths of decibels for the noise measurement data.

Next perform the tests as indicated in the decision blocks for the covariance analysis in the flowchart. There are three possible outcomes.

Case 1 - slopes equal, intercepts equal, accept Hypothesis A.

Case 2 - slopes equal, intercepts not equal, reject Hypothesis A, but assume a constant difference of predicted from measured insertion loss for all L_r.

Case 3 - slopes not equal, reject Hypothesis A; reject Hypothesis B for some L_r if corresponding $\bar{D} = 0$ outside confidence limits.

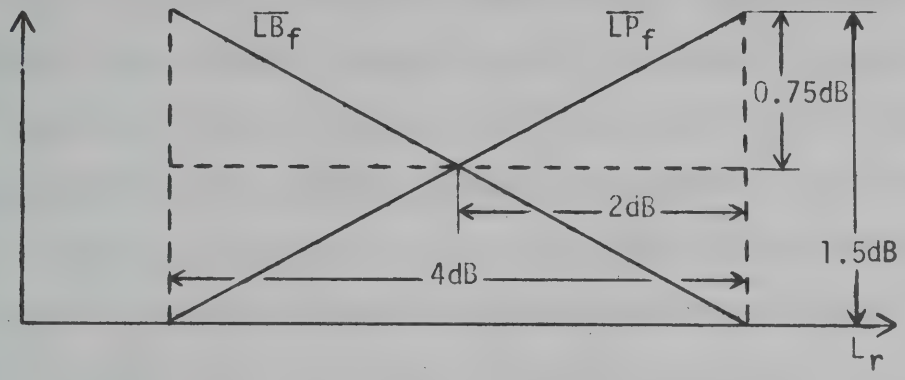
In the first decision block, test equality of slopes for equal variances by comparing the test statistic $t^{\beta}(f)$ to the critical value, t_c, from a table of the t distribution in Reference 2 with f degrees of freedom in a two-tailed test at the 5% level of significance. For unequal variances, $t^{\beta}(f')$ is the Welsh-Aspin approximate t statistic, t'. It can either be compared to t'_c from t distribution tables with f' degrees of freedom or it may be compared to exact critical values t'_c from the tables in Reference 1. If the test statistic is greater than the critical value, reject Hypothesis A and go to test Hypothesis B (Case 3). If the test statistic is less than or equal to the critical value, fail to reject the null

hypothesis of equal slopes. Tentatively accept the hypothesis of equal slopes and go to the next decision block to determine if the regression slopes are close enough to pool. Pooled regression slopes increase the sensitivity of the next test on intercepts. Further, they permit a constant difference between predicted and measured insertion loss to be specified.

The power of the t-test on slopes will be used to determine if slopes estimated from the two regression can be pooled. Similar to the power of the F-test, which essentially enables the pooling of estimated variances of the regressions, the power of the t-test gives the chance of rejecting the null hypothesis when it is not true by an amount greater than a maximum allowable difference, δ_{max}, in true regression slopes, $\delta_{max} = \beta_P - \beta_B$. In effect, amounts less than this maximum allowable difference in true slopes would be acceptable to the experimeter should the null hypothesis be accepted, if it were not really true. In addition, the power of the t-test on slopes can be used to determine sample size required for before and after noise measurements, as will be shown later.

Two elements of the power test on slopes must be specified - the minimum power and the maximum allowable difference. The minimum power will be set arbitrarily high, say 80%, to insure with high probability that the null hypothesis will be rejected when it is not true. Thereby, the test on slopes is required to be sensitive. To determine the maximum allowable difference, δ_{max}, at this power, consider the consequences of the difference in slopes on $\overline{LP}_f - \overline{LB}_f$ at the endpoints of the range of L_r for a particular site. For example, let 1.5 dB be allowable for $\overline{LP}_f - \overline{LB}_f$ over a range of 4 dB at a site. If the true regression lines for $\overline{LB}_f$ and $\overline{LP}_f$ are assumed to

intersect in the center of the range of L_r, the corresponding allowable difference in slopes would be 0.75, as in Figure B1.



$\beta_P = 0.75/2 = 0.375$, $\beta_B = 0.75/2 = -0.375$

$\delta_{max} = \beta_P - \beta_B = 0.375 - (-0.375) = 0.75$

Figure B1 - Maximum Allowable Slope Difference

The statistic d (non-central t) used to determine the power of the t-test, is described in Reference 8, Section 8.4, and Reference 3, Section 14.2. It may be computed from the data by the following formulas:

For equal variances

$$d(f) = \frac{\delta_{max}}{S_D \sqrt{\frac{1}{SSx_A} + \frac{1}{SSx_B}}} \qquad (14a)$$

with f degrees of freedom.

For unequal variances

$$d(f') = \frac{\delta_{max}}{\sqrt{\frac{S_P^2}{SSx_A} + \frac{S_B^2}{SSx_B}}} \qquad (14b)$$

with f' degrees of freedom.

All quantities have been previously defined in equations (7) and (10).

Table A-12b in Reference 2 relates the three parameters - power, degrees of freedom, and statistic d for a particular level of significance of the two-tailed t-test. Simply enter the body of the table at the 5% level of significance (two-tailed) with the computed d for f or f' degrees of freedom and pick off the power. For example, with d = 2.88 and f = 36, the power is 80%. If the power is greater than or equal to the minimum power, then unconditionally accept the null hypothesis of equal slopes and pool the slopes for the test on intercepts. Otherwise, tentatively accept the null hypothesis on equal slopes but do not pool the slopes for the test on intercepts.

Sample size determination in advance of the actual before noise measurements may be initiated using the power of the t-test on equal slopes in reverse. Given the maximum allowable difference in slopes and the minimum power, Table A-12c in Reference 2 may be used to estimate sample size. Certain assumptions must be made to compute a statistic d' (simply d independent of sample size). Namely, the before and after sample sizes and standard deviations of the reference levels, as well as the variances of the LB_f and LP_f regressions are assumed identical. Moreover, the magnitudes of the reference level standard deviations, S_X, and the standard error of estimate of the regressions, S_D, must be estimated. Then d' may be computed as

$$d' = \frac{\delta_{max}}{S_D \sqrt{\frac{2}{S_x^2}}} \qquad (15a)$$

where the standard deviation is related to the sums of squares and sample size:

$$S_x^2 = \frac{SSx}{N-1} \qquad (15b)$$

With d' and the minimum power desired, enter Table A-12c in Reference 2 for the two-tailed t-test at the 5% level of significance (one-tailed at 2.5% in the table). Then pick off a sample size in the body of the table. Because the variance is due to regression, the sample size of the table must be increased by one in order to achieve the correct estimate of sample size. Since a number of assumptions go into this estimate of sample size, a balance must be struck between worst case assumptions and cost of sampling to arrive at a reasonable estimate.

At this point in the flowchart, the decision on pooling slopes is made. If the slopes are close enough to pool (indicated by the power of the t-test), then formulas from Reference 8, Section 14.10 can be used to recompute quantities for the t-test on equal intercepts. We have the pooled slope $\bar{\beta}$ as:

$$\bar{\beta} = \frac{SSx_A\ \hat{\beta}_P + SSx_B\ \hat{\beta}_B}{SSx_A + SSx_B} \tag{16}$$

New intercepts are now:

$$\hat{\alpha}_P = \bar{\bar{L}}P_f - \bar{\beta}\bar{L}_{rB} \tag{17a}$$

$$\hat{\alpha}_B = \bar{\bar{L}}B_f - \bar{\beta}\bar{L}_{rA} \tag{17b}$$

where

$$\bar{\bar{L}}P_f = \frac{\sum LP_{fi}}{N_A} \quad , \quad \bar{L}_{rA} = \frac{\sum L_{ri}}{N_A} \tag{17c}$$

$$i = 1,2,\ldots,N_A$$

$$\bar{\bar{L}}B = \frac{\sum LB_{fj}}{N_B} \quad , \quad \bar{L}_{rB} = \frac{\sum L_{rj}}{N_B} \tag{17d}$$

$$j = 1,2,\ldots,N_B$$

With these quantities, compute new standard errors of estimate for the t-tests on equal intercepts:

For equal variances

$$S_D^2 = \frac{SSy_P + SSy_B - \bar{\beta}^2(SSx_A + SSx_A)}{N_A + N_B - 3} \qquad (18a)$$

$$f = N_A + N_B - 3 \qquad (18b)$$

For unequal variances

$$S_P^2 = \frac{SSy_P - \bar{\beta}^2 SSx_A}{N_A - 2} \qquad (18c)$$

$$S_B^2 = \frac{SSy_B - \bar{\beta}^2 SSx_B}{N_B - 2} \qquad (18d)$$

If the slopes can be pooled, substitute equations (18) into equations (11) governing the t-test on equal intercepts. Otherwise, use equations (11) as they stand. Then find critical values t_c or t'_c (as for equality of slopes) in a two-tailed t-test at the 5% level of significance. As indicated in the next decision block, if the test statistic is less than or equal to the critical value, fail to reject the null Hypothesis A (Case 1). Conclude that the barrier design method under test predicts measured insertion loss within experimental error. Proceed with next design method to be tested to the top of the barrier design method loop in the flowchart and repeat the analysis.

If the test statistic is greater than the critical value, reject Hypothesis A. However, since the equal slopes hypothesis has not been rejected at this point, it may be concluded that the difference, $\bar{D}$, between predicted and measured barrier insertion loss is a constant with respect to traffic

conditions (Case 2). Moreover, if the slopes have been pooled, then this constant, non-zero difference may be estimated with confidence limits established following the discussion in Reference 8, Section 14.10. Since $\hat{\alpha}_p$, $\hat{\alpha}_B$, S_D, S_p, and S_B have new values computed in equations (17) and (18) from common slope $\bar{\beta}$, the regression equations may be expressed as:

$$\hat{LB}_f = \bar{\beta}L_r + \hat{\alpha}_p \qquad (19a)$$

$$\hat{LP}_f = \bar{\beta}L_r + \hat{\alpha}_B \qquad (19b)$$

Thus the average difference, $\bar{D}$, can be estimated by the constant difference $\hat{D}$ between these equations:

$$\hat{D} = \hat{LP}_f - \hat{LB}_f \qquad (20a)$$

from equations (19),

$$\hat{D} = \hat{\alpha}_p - \hat{\alpha}_B \qquad (20b)$$

The confidence limits about $\hat{D}$ to estimate $\bar{D}$ are as follows:

For equal variances

$$\bar{D} \text{ between } \hat{D} \pm t_c S_D \sqrt{\frac{1}{N_A} + \frac{1}{N_B} + \frac{(L_{rA}-L_{rB})^2}{SSx_A + SSx_B}} \qquad (21a)$$

For unequal variances

$$\bar{D} \text{ between } \hat{D} \pm t'_c \sqrt{S_p^2\left[\frac{1}{N_A} + \frac{(\bar{L}_{rA}-\bar{L}_{rB})^2 SSx_A}{(SSx_A + SSx_B)^2}\right] + S_B^2\left[\frac{1}{N_B} + \frac{(\bar{L}_{rA}-\bar{L}_{rB})^2 SSx_B}{(SSx_A + SSx_B)^2}\right]} \qquad (21b)$$

After this step proceed with the next design method to be tested to the top of the barrier design method loop in the flowchart and repeat the analysis.

If the hypothesis of equal slopes has been rejected for the design method under test, then Hypothesis B must be tested as indicated under Case 3 in the flowchart. This may be graphically done by plotting the upper and lower confidence limits about $\bar{D}$ against L_r given by Hypothesis B formula (13). A hyperbola will be formed about the line $\hat{D}(L_r)$. The true average difference between predicted and measured insertion loss lies between the region bounded by the hyperbola and the range of L_r in the data. Therefore, for any point in the intervals along the L_r axis (i.e. $\bar{D} = 0$) which lie outside this region, the null hypothesis $\bar{D} = 0$ is rejected at the 5% level of significance. An example plot of this situation is given in Figure B2.

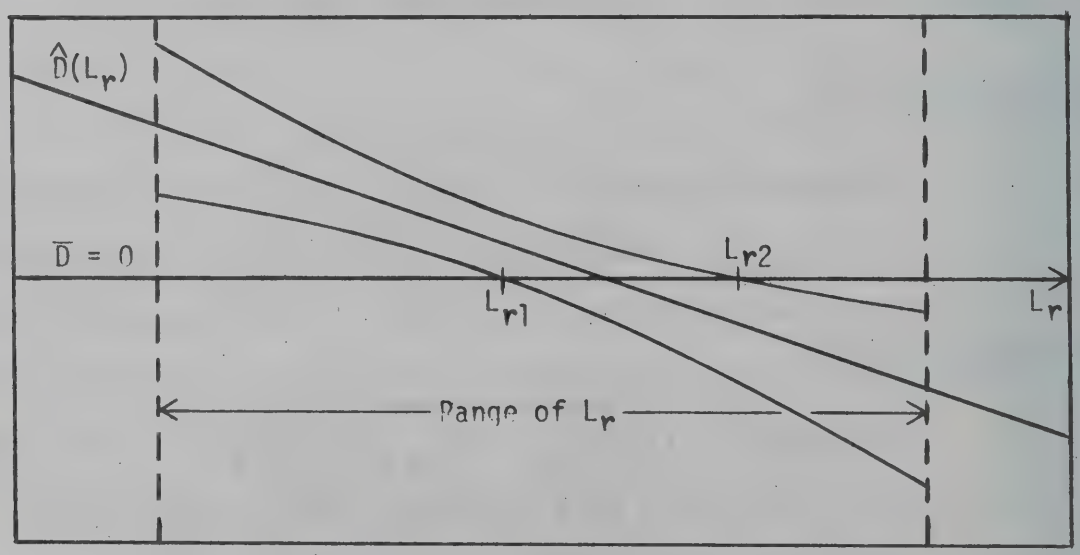


Figure B2 - Graphical Test of Hypothesis B

In the plot of Figure B2, reject the null hypothesis for L_r less than L_{r1} and L_r greater than L_{r2} within the range of L_r indicated. Note that the points L_{r1} and L_{r2} could be obtained by numerical techniques by finding roots of the general equations:

$$\overline{D} = \hat{D}(L_r) \pm \sqrt{2F}\, q(L_r) = 0 \qquad (22)$$

These equations were derived from the general expression for confidence limits of formula (12) above.

After the L_r reject intervals have been identified, the correlations between L_r and traffic variables derived from step-wise regression performed earlier can be used to qualitatively ascertain the traffic situations which may be causing discrepancies between predicted and measured insertion loss. A discussion of this point is found in the subsection of the report entitled "Influence of Traffic Variables." As before, for Case 1 and Case 2, proceed with the next design method to the top of the barrier design method loop in the flowchart and repeat the analysis.

When all P barrier design methods' predictions have been compared against measured insertion loss at a given site, the next step is to compute the measured barrier insertion loss, A_m, as a function of L_r. This is done with formulas for confidence limits similar to those for Hypothesis B, except that LA_f, the measured after field noise levels, replace LP_f, the predicted before field levels. A preliminary test of equality of variances of the previously obtained LB_f and LA_f regressions, estimated by the squares of the standard errors of estimate, S_B^2 and S_A^2, must be performed. This can be done exactly as before for the variances of the LB_f and LP_f regressions. Given

the two regressions then:

$$\widehat{LB}_f = \hat{\beta}_B L_r + \hat{\alpha}_B \tag{23a}$$

$$\widehat{LA}_f = \hat{\beta}_A L_r + \hat{\alpha}_A \tag{23b}$$

The measured insertion loss is the difference:

$$\hat{A}_m(L_r) = \widehat{LB}_f - \widehat{LA}_f \tag{24a}$$

$$\hat{A}_m(L_r) = (\hat{\beta}_B - \hat{\beta}_A)L_r + (\hat{\alpha}_B - \hat{\alpha}_A) \tag{24b}$$

The expected value of $\hat{A}_m(L_r)$ is $\bar{A}_m$, the average insertion loss for given L_r. The value of $\bar{A}$ has confidence limits given by the following formulas:

For equal variances

$$\bar{A} \text{ between } \hat{A}(L_r) \pm \sqrt{2F_{.95}(2,f)}\, S_m \sqrt{\frac{1}{N_B} + \frac{(L_r - \bar{L}_{rB})^2}{SSx_B} + \frac{1}{N_A} + \frac{(L_r - \bar{L}_{rA})^2}{SSx_A}} \tag{25a}$$

where the pooled standard error of estimate S_m is found by

$$S_m^2 = \frac{(N_B - 2)S_B^2 + (N_A - 2)S_A^2}{N_B + N_A - 4}$$

with $f = N_B + N_A - 4$ degrees of freedom.

For unequal variances

$$\bar{A}_m \text{ between } \hat{A}_m(L_r) \pm \sqrt{2F_{.95}(2,f')} \sqrt{S_B^2\left[\frac{1}{N_B} + \frac{(L_r - \bar{L}_{rB})^2}{SSx_B}\right] + S_A^2\left[\frac{1}{N_A} + \frac{(L_r - \bar{L}_{rA})^2}{SSx_A}\right]} \tag{25b}$$

with f' degrees of freedom.

All quantities in the above formulas with respective degrees of freedom are as defined in the Hypothesis B formulas (13), with the LA_f regression quantities substituted for the LP_f regression quantities (simply replace subscript "P" with "A").

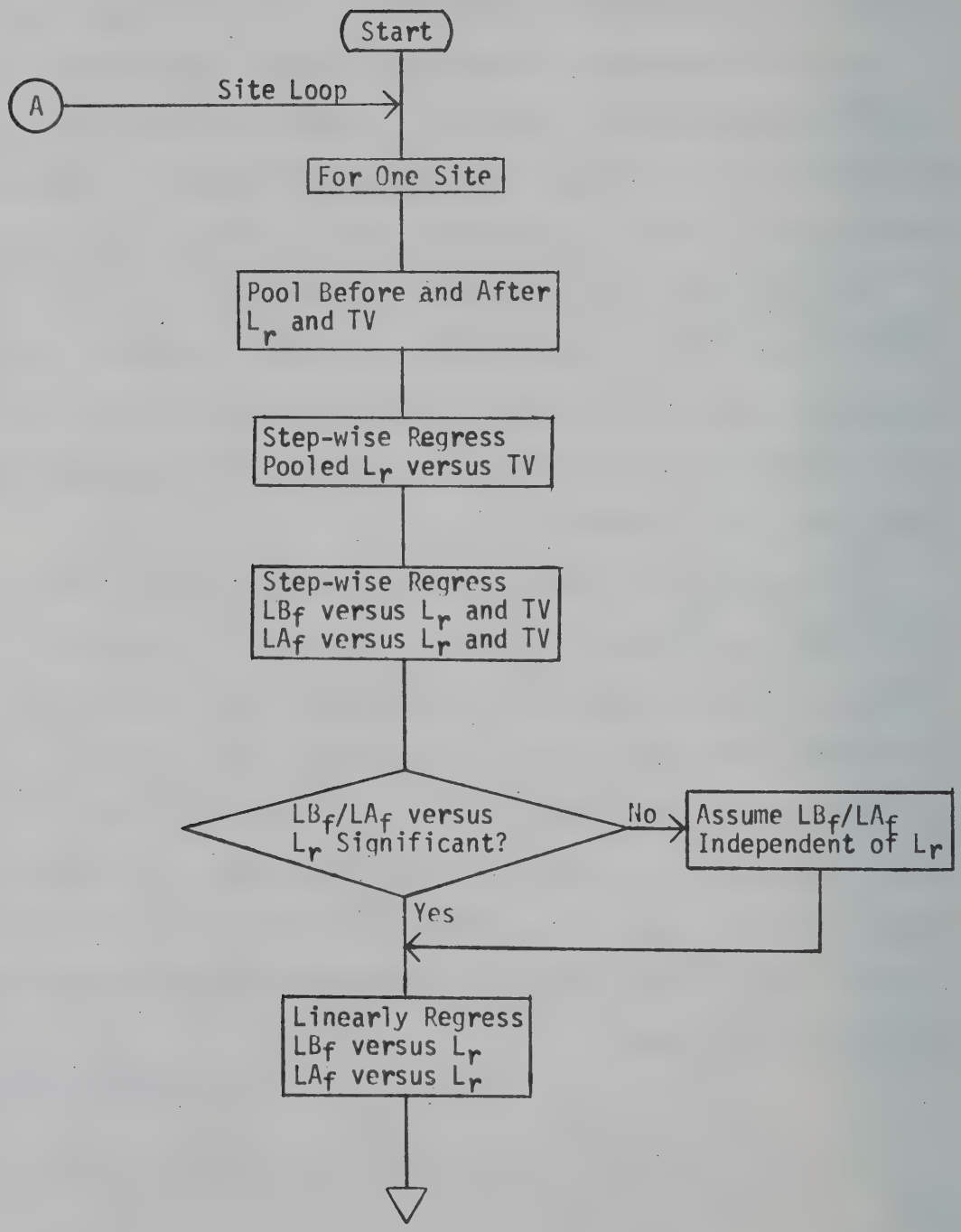
With the computation of confidence intervals for measured insertion loss, the particular site is finished. Consider the next site and proceed to the top of the site loop in the flowchart. Repeat all succeeding steps until all the S sites have been treated for all the P barrier design methods.

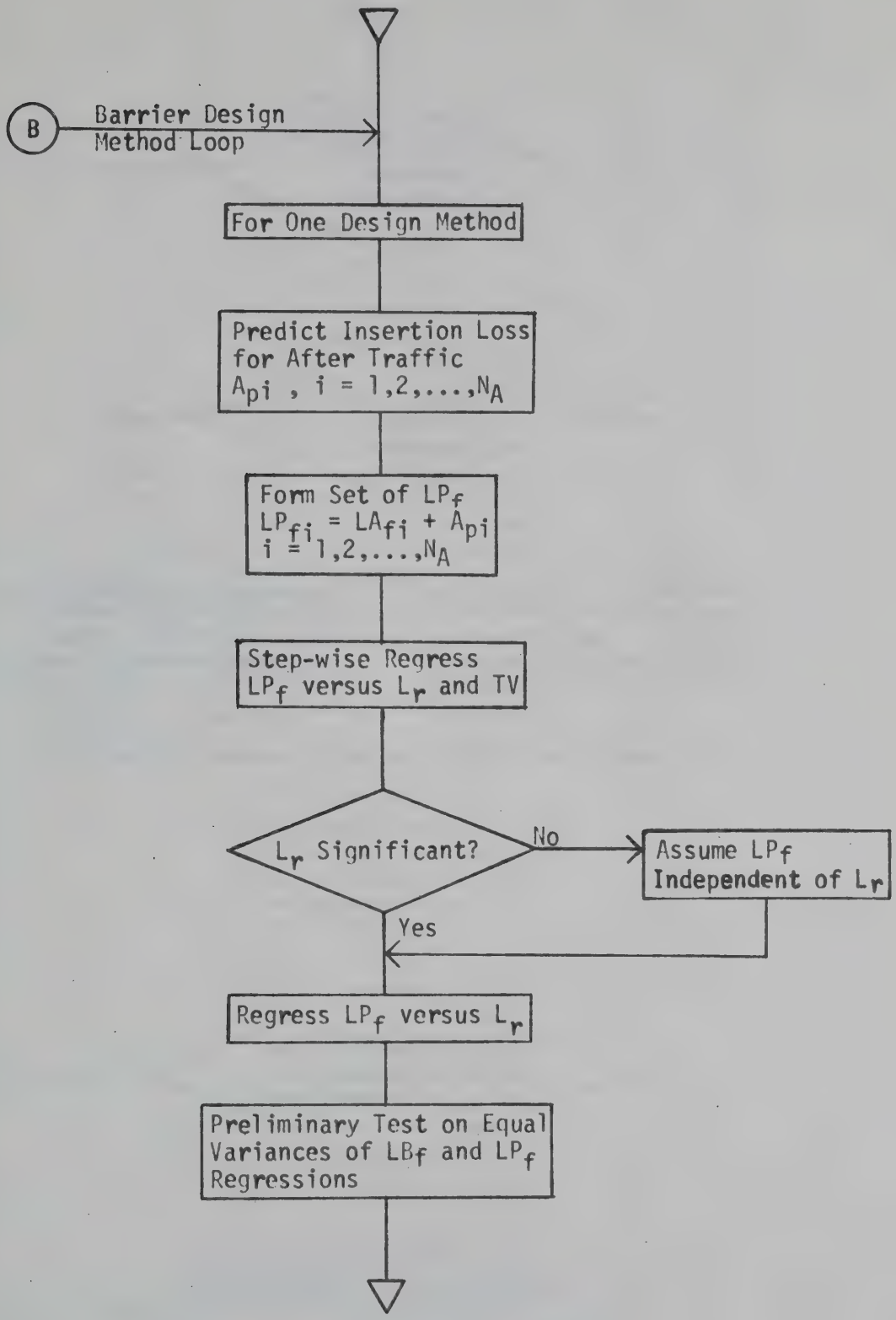
The final step in the procedure is to evaluate each barrier design method in terms of the range of sites and traffic conditions it fails the statistical tests. As a measure of performance the results from all sites may be tabulated for each of the design methods in terms of the Case 1, Case 2, and Case 3 categories.

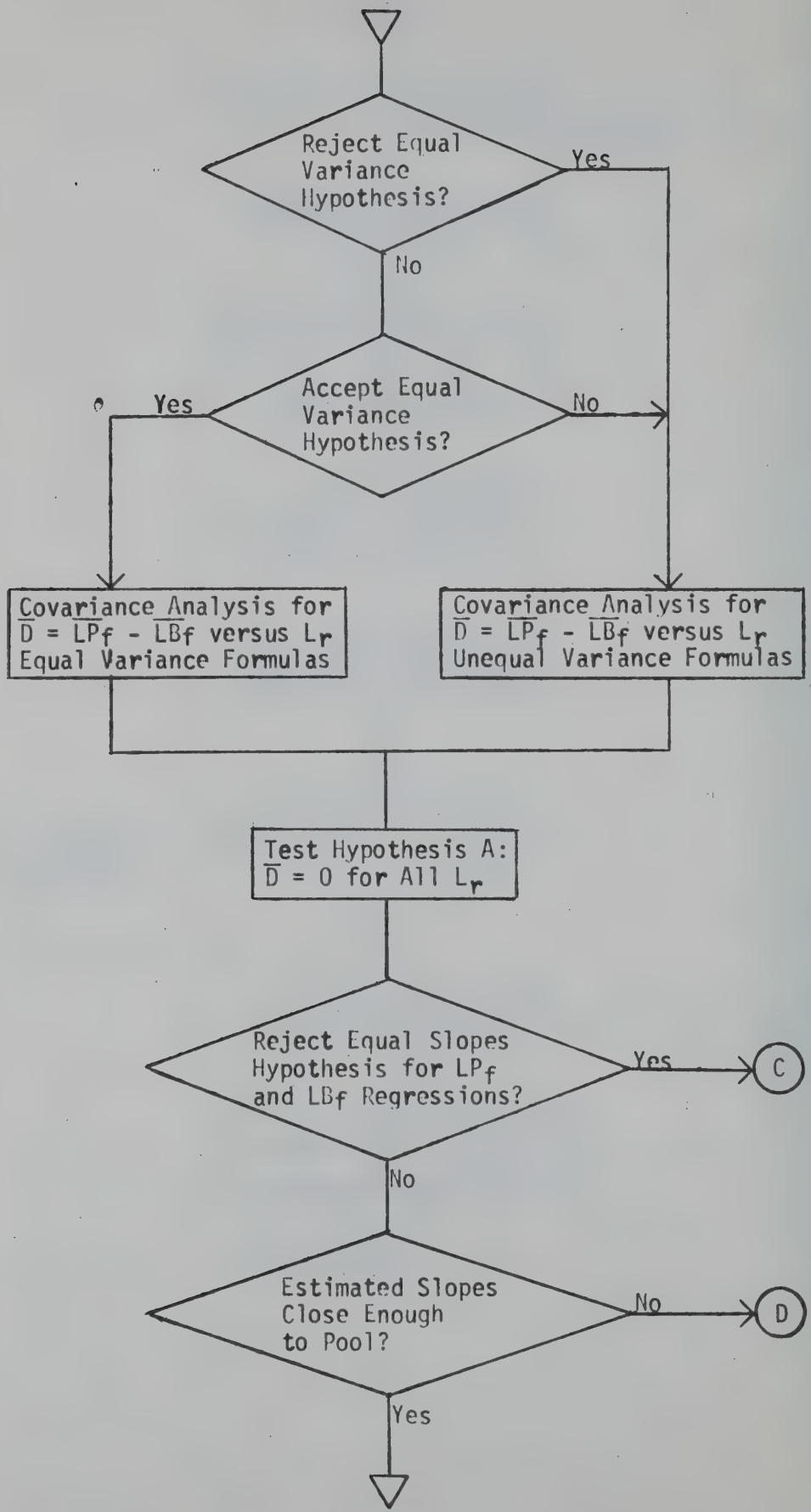
To facilitate the evaluation, and index can be established for barrier design method performance by weighting the number of sites falling into each category. For example, Case 1 sites would have unit weight; Case 2 sites, half weight. For Case 3 sites, some positive weight could be assigned based on the range of L_r over which Hypothesis B failed to be rejected for each site. A possibility is one-third weight multiplied by the ratio of this range to the full range of L_r. The index would be the sum of these weights over all sites for each design method. It could then be compared against a possible perfect score.

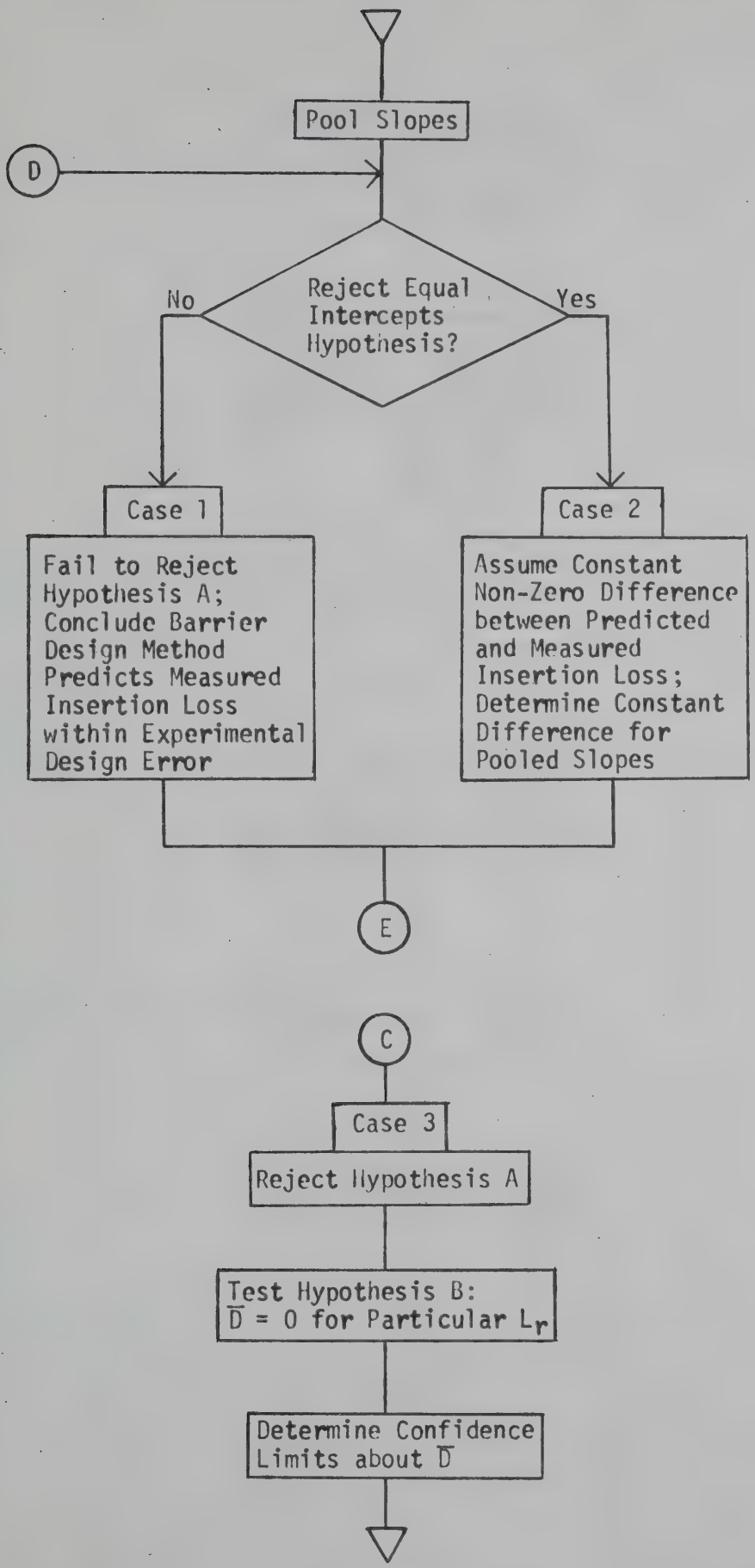
Figure B3

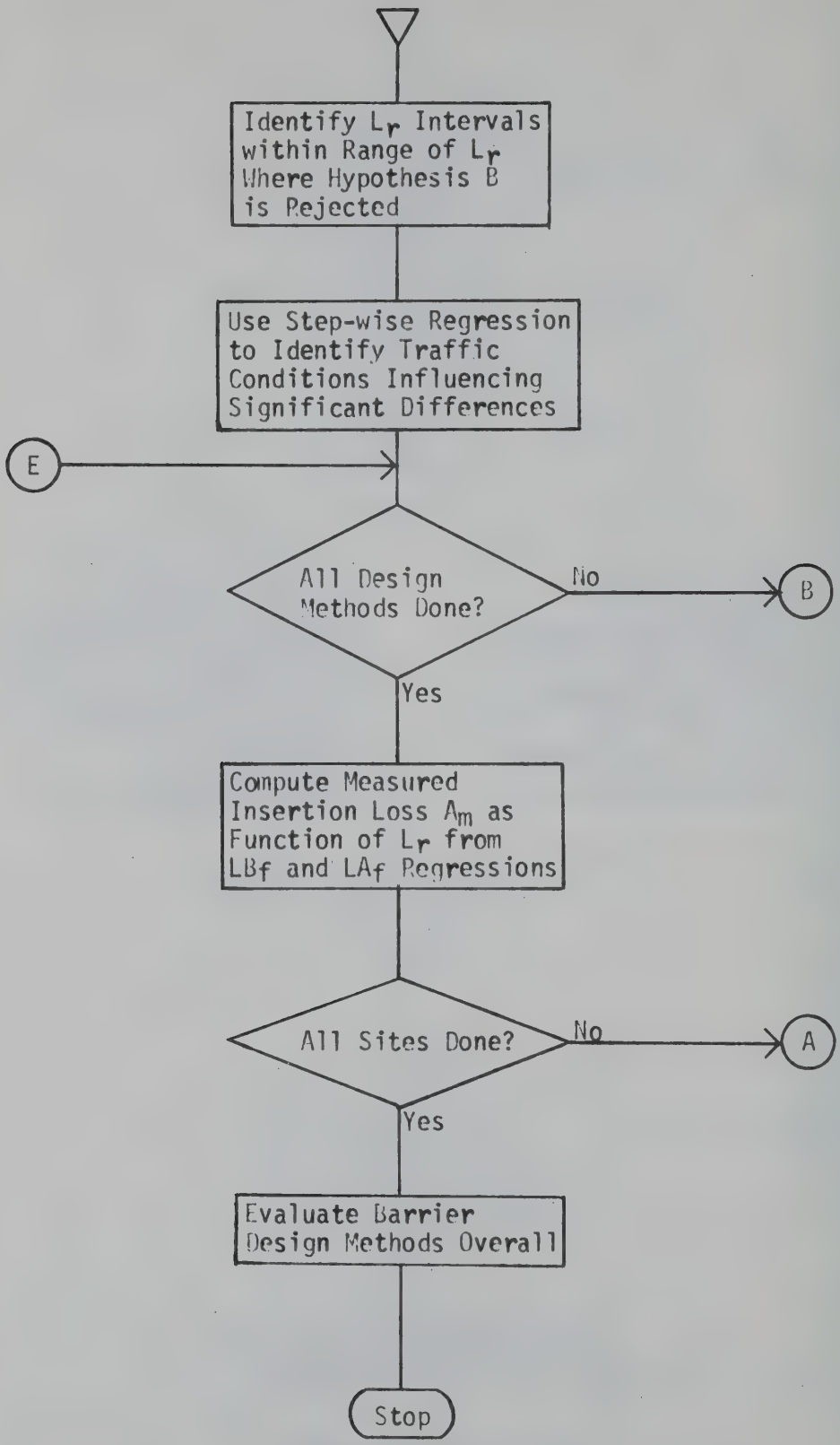
Flow Chart of Procedure for
Evaluating Barrier Design Methods




B
Barrier Design Method Loop
For One Design Method
Predict Insertion Loss for After Traffic A_{pi} , i = 1,2,...,N_A
Form Set of LP_f $LP_{fi} = LA_{fi} + A_{pi}$ i = 1,2,...,N_A
Step-wise Regress LP_f versus L_r and TV
L_r Significant?
No
Assume LP_f Independent of L_r
Yes
Regress LP_f versus L_r
Preliminary Test on Equal Variances of LB_f and LP_f Regressions


Reject Equal Variance Hypothesis?
Yes
No
Accept Equal Variance Hypothesis?
Yes
No
Covariance Analysis for $\overline{D} = \overline{LP_f} - \overline{LB_f}$ versus L_r Equal Variance Formulas
Covariance Analysis for $\overline{D} = \overline{LP_f} - \overline{LB_f}$ versus L_r Unequal Variance Formulas
Test Hypothesis A: $\overline{D} = 0$ for All L_r
Reject Equal Slopes Hypothesis for LP_f and LB_f Regressions?
Yes
C
No
Estimated Slopes Close Enough to Pool?
No
D
Yes


Pool Slopes
D
Reject Equal Intercepts Hypothesis?
No
Yes
Case 1
Fail to Reject Hypothesis A; Conclude Barrier Design Method Predicts Measured Insertion Loss within Experimental Design Error
Case 2
Assume Constant Non-Zero Difference between Predicted and Measured Insertion Loss; Determine Constant Difference for Pooled Slopes
E
C
Case 3
Reject Hypothesis A
Test Hypothesis B: $\bar{D} = 0$ for Particular L_r
Determine Confidence Limits about $\bar{D}$


Identify L_r Intervals within Range of L_r Where Hypothesis B is Rejected
Use Step-wise Regression to Identify Traffic Conditions Influencing Significant Differences
E
All Design Methods Done?
No
B
Yes
Compute Measured Insertion Loss A_m as Function of L_r from LB_f and LA_f Regressions
All Sites Done?
No
A
Yes
Evaluate Barrier Design Methods Overall
Stop

APPENDIX C

Site Plans

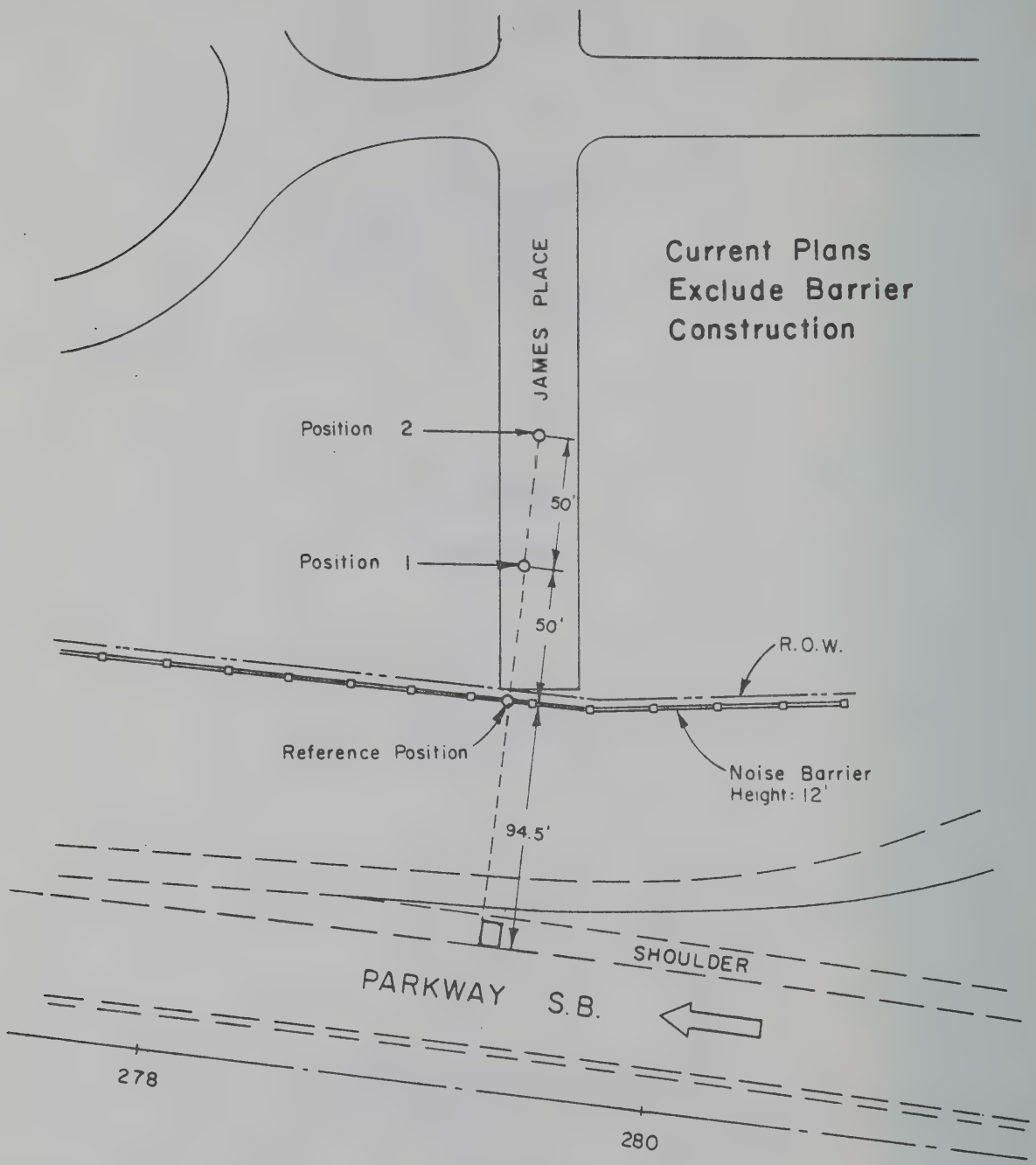


Figure C-1

Measurement Positions at James Place

Current Plans
Include Barrier
Construction

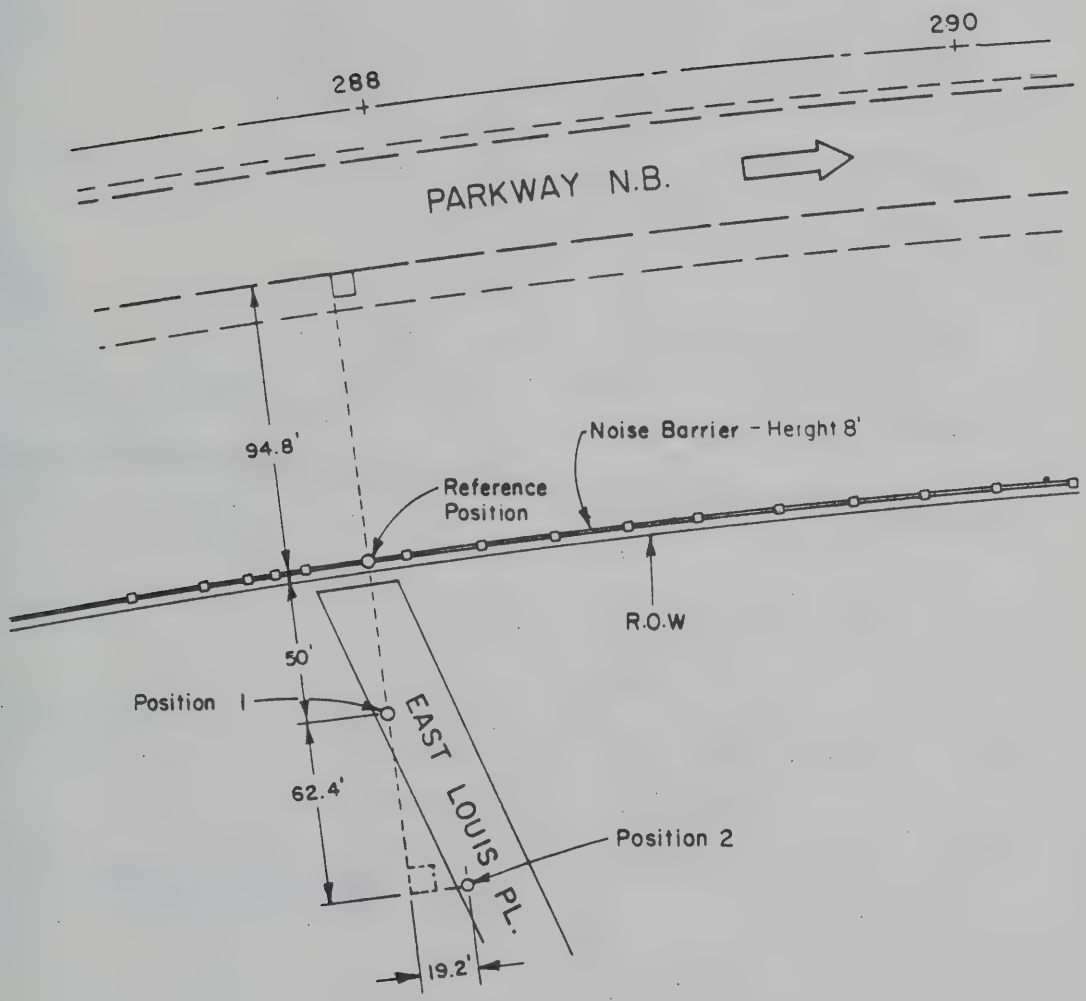


Figure C-2

Measurement Positions at East Louis Pl.

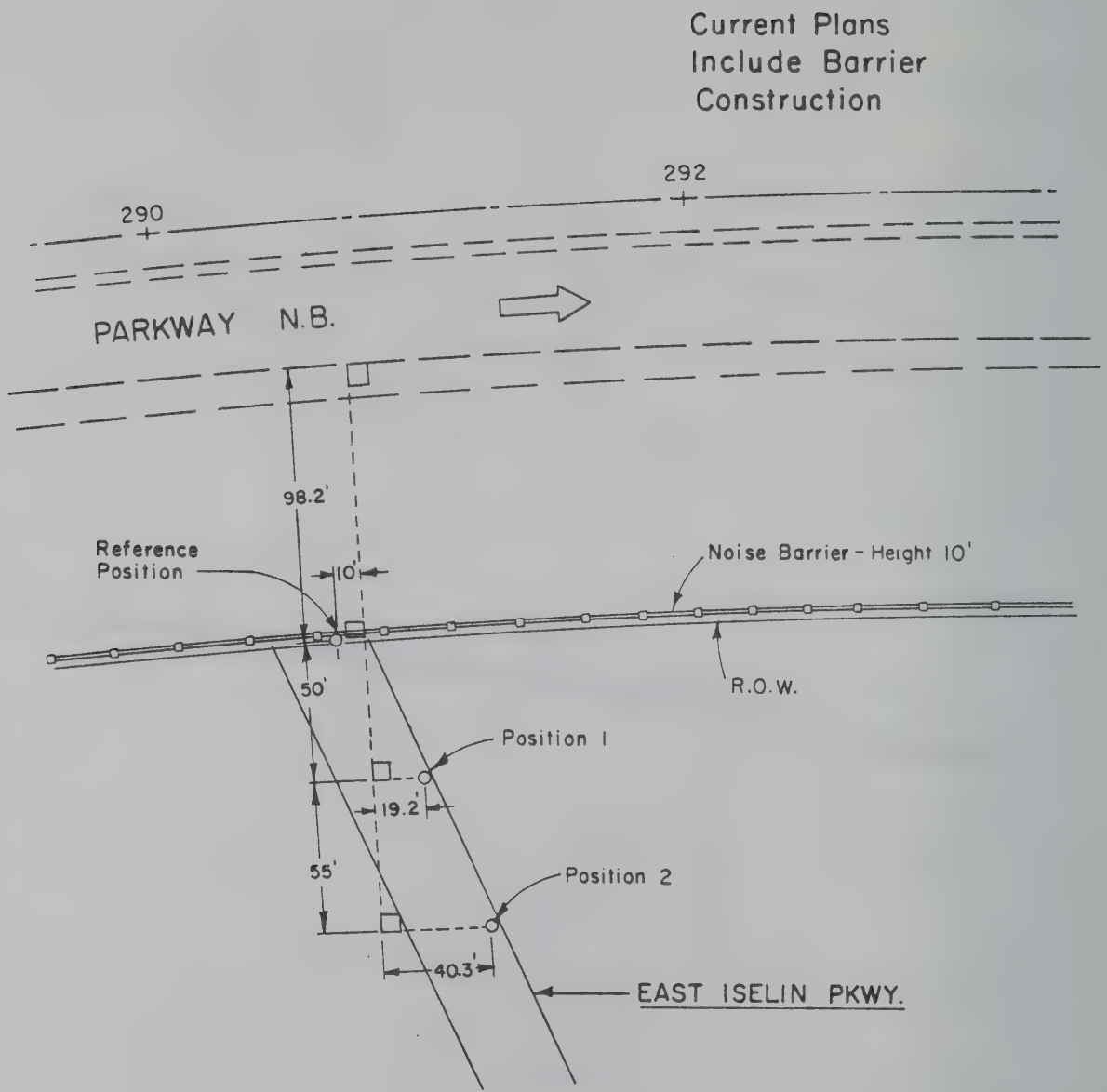


Figure C-3

Measurement Positions at East Iselin Pkwy.

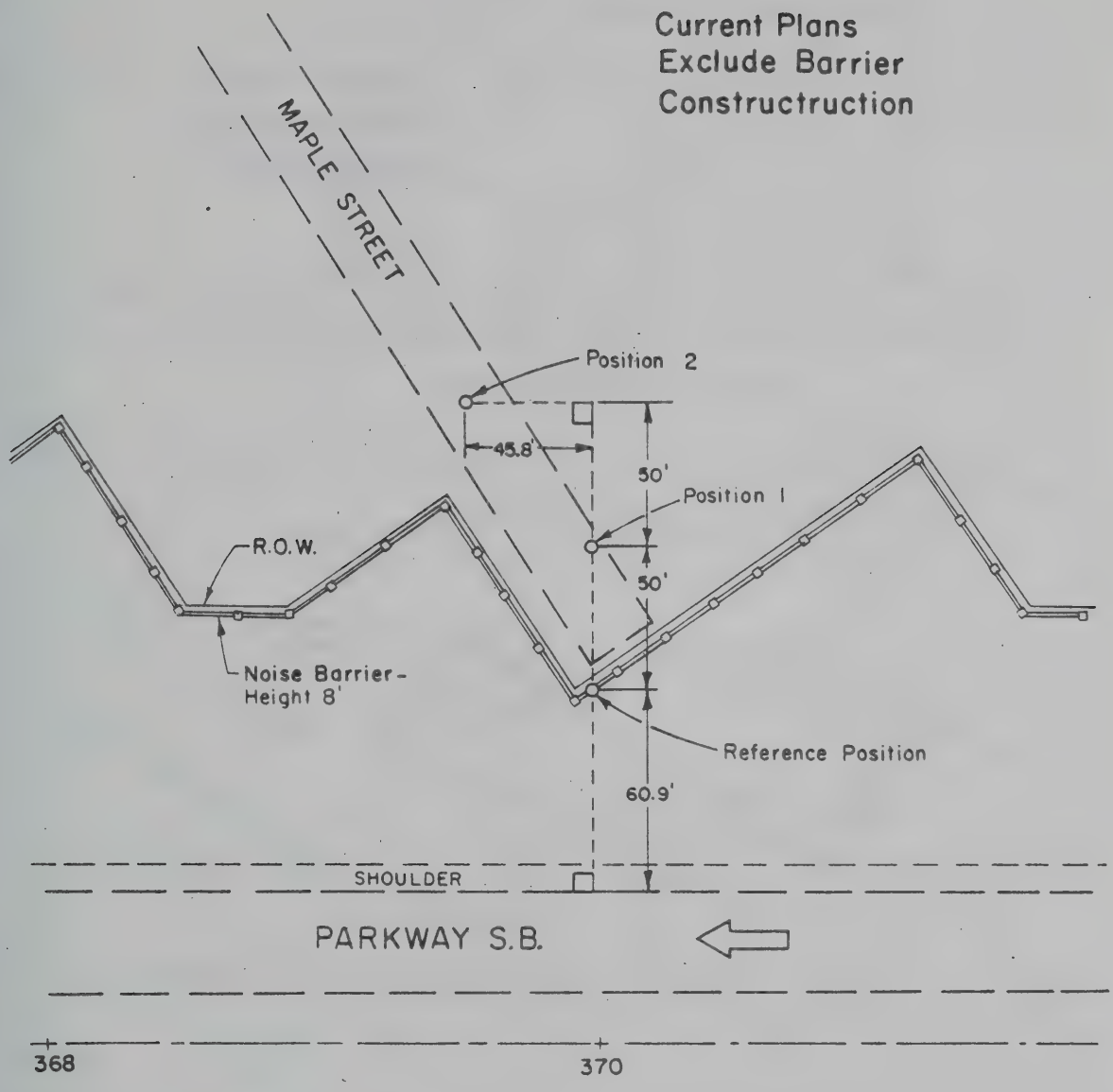


Figure C-4

Measurement Positions at Maple Street

Current Plans
Exclude Barrier
Construction

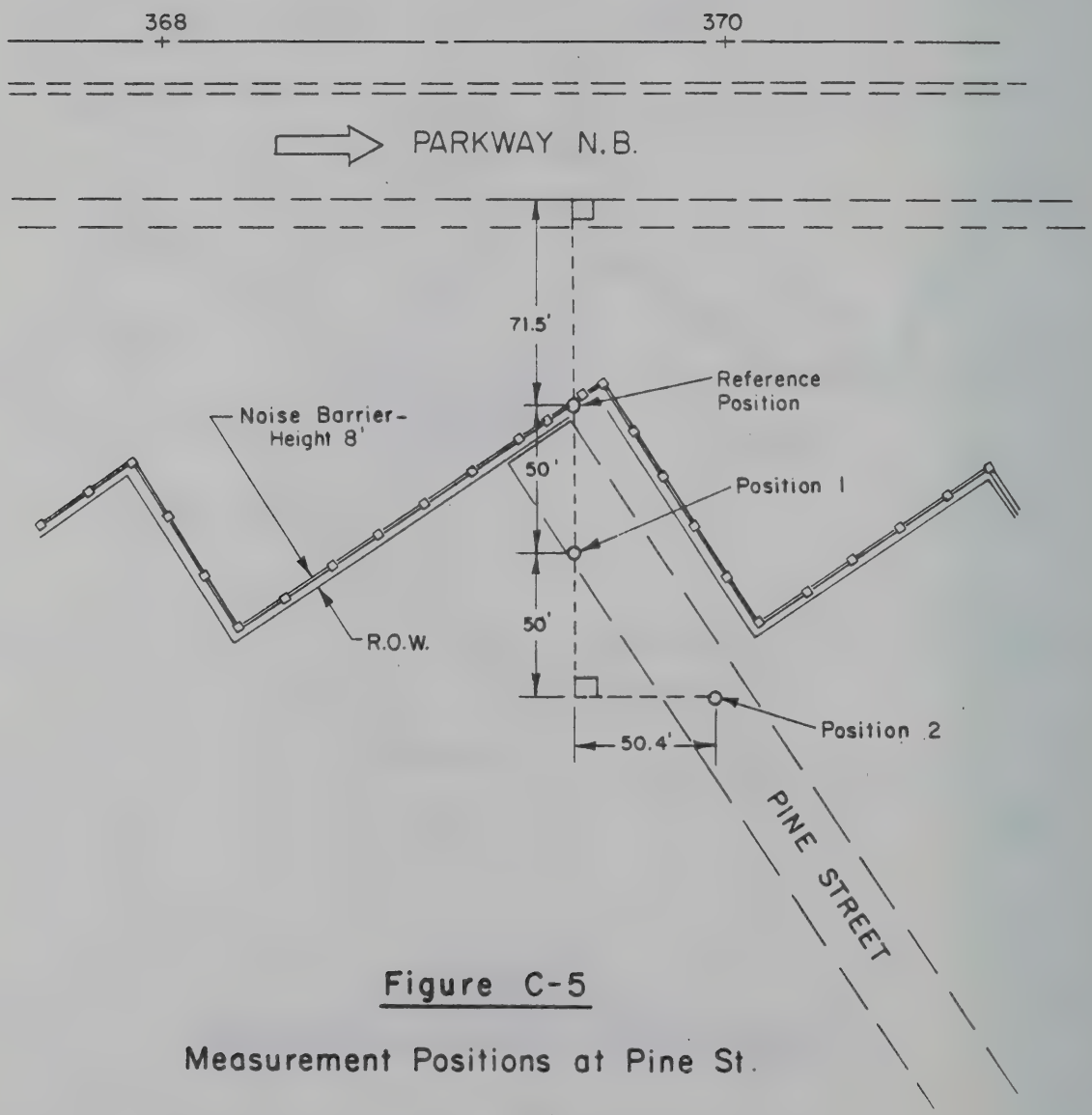


Figure C-5

Measurement Positions at Pine St.

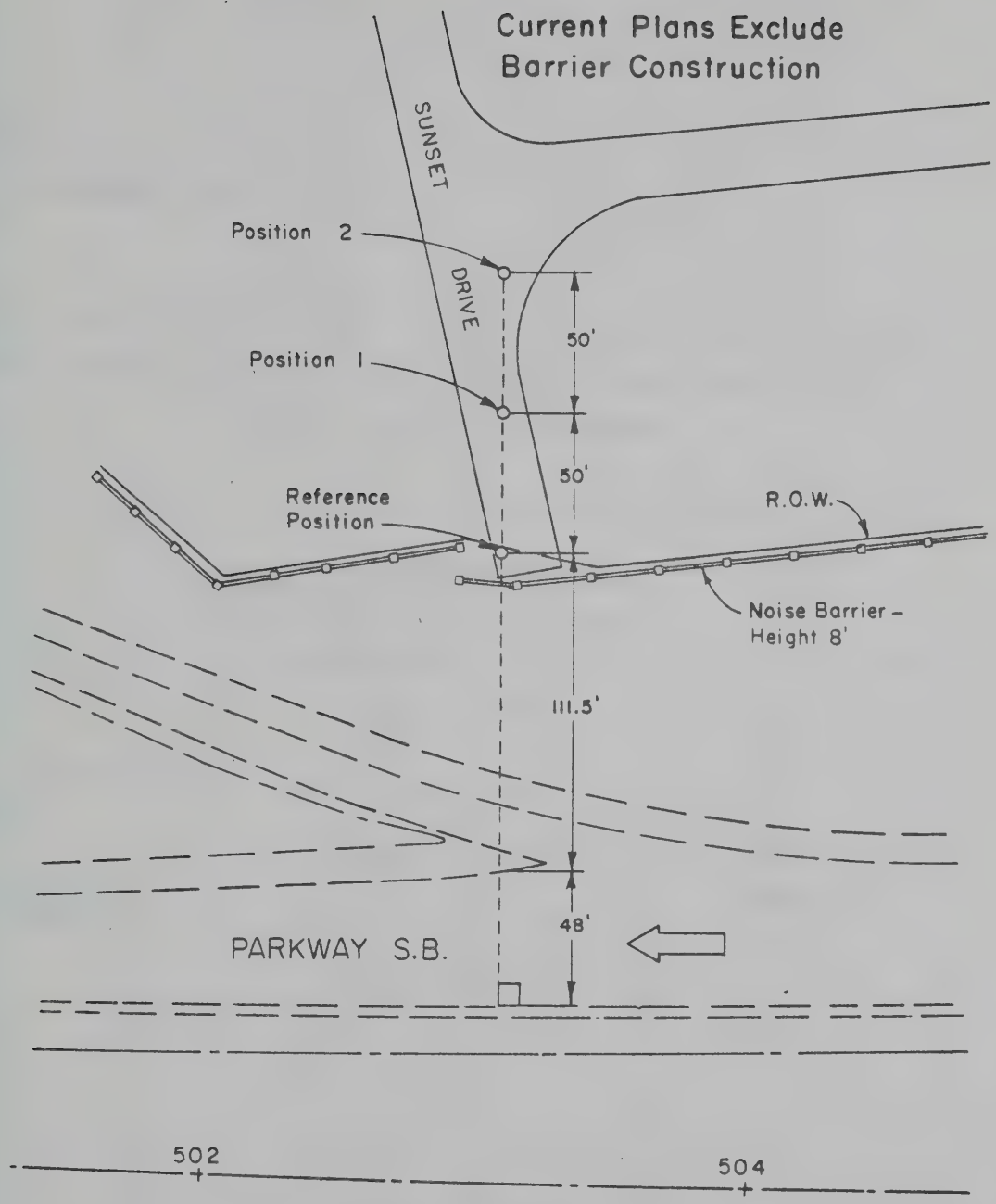


Figure C-6

Measurement Positions at Sunset Drive

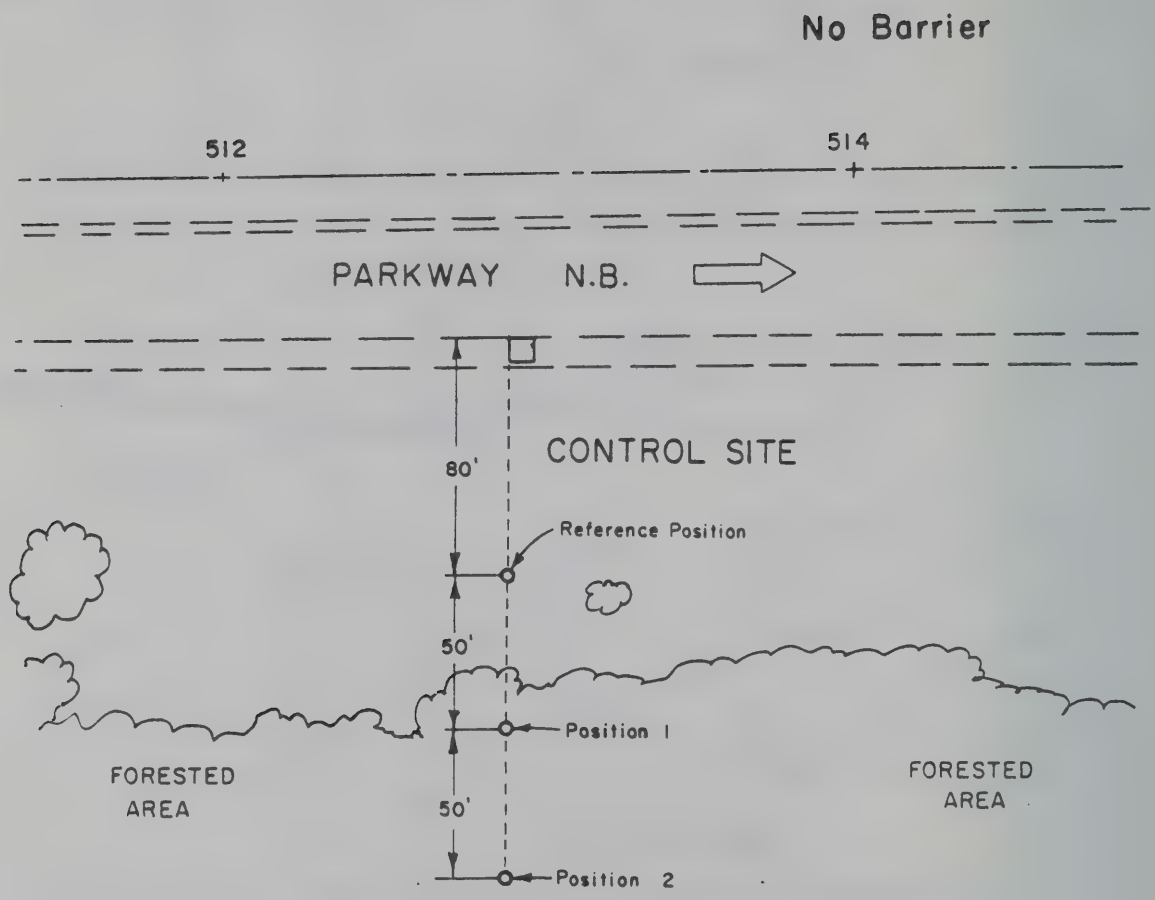


Figure C-7

Measurement Position at the Control Site

APPENDIX D

D.1 Noise Measurement Data

LOCATION: JAMES PLACE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
2	80.3	78.5	69.2	66.8	300	0	204	1	N/A	N/A
3	81.8	79.3	68.9	66.2	291	1	246	1	N/A	N/A
9	83.6	80.8	69.1	66.8	263	0	248	2	N/A	N/A
12	80.6	78.6	68.6	65.8	255	1	252	0	N/A	N/A
13	81.1	79.1	69.1	66.6	274	0	267	0	N/A	N/A
14	81.1	79.1	69.2	67.0	293	0	291	0	N/A	N/A
18	80.4	78.5	68.6	65.8	297	1	303	1	N/A	N/A
19	81.3	79.2	69.1	66.6	295	0	307	0	N/A	N/A
20	81.0	78.8	69.1	66.7	273	1	345	4	N/A	N/A
25	80.4	78.4	69.7	67.8	264	0	203	1	N/A	N/A
32	79.6	77.7	72.6	69.9	263	0	246	2	N/A	N/A
37	80.0	78.3	71.2	69.2	333	3	299	1	N/A	N/A
39	79.7	77.9	72.5	69.9	297	0	282	3	N/A	N/A
43	81.0	79.0	70.4	68.6	346	0	227	0	N/A	N/A
45	80.5	78.7	73.7	71.0	369	2	252	3	N/A	N/A
48	79.7	78.0	72.5	69.7	364	0	232	1	N/A	N/A
49	80.4	78.5	70.7	68.8	330	2	270	0	N/A	N/A
51	81.0	79.0	72.3	69.7	325	1	272	1	N/A	N/A
52	80.2	78.4	71.7	69.4	315	0	275	1	N/A	N/A
53	79.8	77.8	71.2	69.0	323	2	284	1	N/A	N/A
54	80.0	78.2	73.6	70.6	362	0	251	0	N/A	N/A
59	80.2	78.4	73.7	70.9	369	0	299	1	N/A	N/A

LOCATION: JAMES PLACE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
63	79.4	77.2	68.9	66.3	231	1	151	0	56.8	6.3
67	79.9	77.9	69.0	66.5	278	1	171	0	55.1	6.5
68	79.4	77.4	69.2	66.8	270	0	163	0	54.6	6.6
69	79.3	77.0	68.9	66.3	235	1	138	0	56.7	6.8
70	79.2	76.9	68.4	65.6	229	0	171	0	55.5	6.3
71	79.3	77.2	68.6	65.8	292	1	203	0	54.8	5.8
75	79.6	77.5	69.0	66.4	254	0	244	0	N/A	N/A
76	79.2	76.8	68.9	66.1	284	0	195	0	N/A	N/A
78	79.5	77.4	69.0	66.3	255	1	220	2	N/A	N/A

LCCATION: JAMES PLACE FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
21	79.9	78.1	64.5	62.7	241	2	223	0	55.3	6.4
22	79.6	77.6	64.3	62.3	262	0	179	0	57.3	7.3
24	79.6	77.7	64.3	62.4	245	1	215	0	57.7	6.8
29	79.5	77.5	64.7	63.0	246	1	178	0	56.5	6.9
30	79.9	77.8	64.8	63.1	251	0	193	1	56.3	6.2
31	79.5	77.7	64.9	63.2	290	0	173	0	55.5	6.3
32	80.0	78.1	65.4	63.7	250	0	165	0	55.7	6.5
37	80.6	78.7	66.0	64.1	307	0	219	0	57.7	6.1
40	80.6	78.7	65.9	64.0	326	0	228	0	54.6	6.4
46	80.5	78.5	65.4	63.6	251	1	228	0	57.2	7.6
51	80.9	78.8	68.4	65.5	283	1	278	0	55.7	7.5
52	80.3	78.3	64.7	62.9	294	0	290	0	56.9	7.1
69	81.2	78.9	64.1	61.6	209	1	169	0	61.4	7.5
72	81.4	78.8	64.0	61.4	218	1	202	0	61.2	7.0
8'	80.9	78.8	69.9	68.0	169	1	176	0	N/A	N/A
17'	82.0	79.4	64.4	62.3	224	0	225	0	N/A	N/A
20'	83.0	80.2	64.4	62.6	293	0	263	0	N/A	N/A
24'	81.4	78.9	63.5	60.6	206	0	188	0	61.1	7.1
26'	81.2	78.8	63.2	60.4	180	0	162	0	60.8	7.5
28'	81.7	78.9	63.3	60.5	188	0	123	0	62.5	7.6
30'	82.3	79.4	63.8	61.1	180	1	159	1	63.5	7.0

'THESE OBSERVATIONS WERE TAKEN UNDER A DIFFERENT SAMPLE NUMBER, AND THEREFORE FOLLOW A DIFFERENT SEQUENCE.

LOCATION: E. LOUIS PL. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
10	79.2	76.9	68.2	65.4	289	0	264	0	58.7	5.7
11	79.0	76.4	67.3	64.7	271	0	303	0	57.2	6.4
13	79.1	76.7	68.3	65.5	302	2	300	0	57.7	7.0
27	79.2	77.0	69.0	66.5	268	2	279	0	57.5	5.7
28	79.2	76.9	68.9	66.3	294	1	330	0	56.3	5.8
29	79.3	77.1	69.1	66.6	284	1	326	0	57.7	6.5
30	79.3	76.9	69.0	66.5	300	1	335	0	56.9	6.5
43	79.2	76.8	68.6	65.7	241	0	307	0	N/A	N/A
46	79.0	76.4	68.0	65.2	226	1	322	2	58.8	7.4
49	79.0	76.5	68.0	65.2	261	0	348	0	58.5	6.1
50	79.2	76.8	68.6	65.7	266	2	351	1	59.1	6.3
51	79.1	76.6	68.5	65.7	281	0	389	0	57.8	6.7
52	79.2	76.7	68.1	65.2	281	0	295	1	58.1	6.7
57	79.4	77.4	69.0	66.5	366	0	350	0	60.2	6.8
60	79.3	77.1	68.7	65.9	303	0	356	0	60.9	6.1
61	79.2	76.9	68.8	66.1	303	0	351	0	61.8	5.0
64	79.3	77.2	68.9	66.3	342	0	280	0	59.0	5.5
66	79.0	76.4	68.4	65.5	232	0	343	0	61.6	5.6
67	79.1	76.6	68.8	66.1	264	0	315	0	62.7	6.3

LOCATION: E. LOUIS PL. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
2	78.2	75.3	64.7	63.1	324	2	343	0	60.7	5.9
4	77.8	74.9	64.6	62.8	297	0	408	0	60.4	6.8
5	78.3	75.4	64.7	63.0	347	0	394	0	59.4	4.9
7	78.5	75.6	64.9	63.2	338	0	462	0	59.3	6.7
10	77.5	74.7	64.4	62.5	311	3	401	0	56.4	5.6
11	77.7	74.9	64.6	62.8	278	0	394	1	57.3	6.0
14	75.6	73.7	64.4	62.5	317	0	316	3	54.4	6.0
37	77.5	74.8	64.5	62.7	302	1	350	0	61.1	5.3
39	78.3	75.3	64.8	63.1	308	0	285	0	57.8	5.6
42	78.7	76.0	64.6	62.9	405	1	328	0	58.2	5.1
43	78.8	76.1	65.0	63.3	391	1	333	0	58.4	6.4
45	78.8	76.1	64.9	63.2	482	0	325	0	57.4	6.2
46	78.8	76.1	65.6	63.8	287	2	373	0	58.2	5.8
47	78.0	75.2	64.5	62.7	281	0	393	0	58.7	5.1
48	78.6	75.8	64.8	63.1	313	1	370	0	58.3	6.3
50	77.7	74.9	64.5	62.7	215	4	355	0	58.3	6.3
53	78.4	75.4	64.6	62.8	257	0	313	0	59.4	6.5
55	78.3	75.5	64.8	63.2	256	2	402	0	58.3	6.5
56	78.2	75.3	64.6	62.8	272	1	258	0	57.9	6.4
57	78.1	75.0	64.2	62.0	227	2	274	0	58.1	5.9
58	78.5	75.6	64.3	62.2	247	1	255	0	59.4	6.3
61	78.7	75.9	64.3	62.2	254	1	262	1	58.5	6.8

LOCATION: E. LOUIS PL. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
62	78.8	76.0	64.3	62.2	258	1	307	1	58.0	6.4
63	78.8	76.0	64.4	62.4	230	4	284	0	59.0	5.4
64	78.0	75.1	64.3	62.3	248	0	242	0	56.6	5.3

LOCATION: E. ISELIN PKWY. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
1	79.0	76.5	69.5	67.5	236	1	346	1	59.2	5.7
3	78.9	76.2	69.4	67.3	260	0	335	2	58.9	6.1
4	79.1	76.6	69.5	67.6	219	1	305	3	59.4	5.4
6	78.9	76.1	69.3	67.1	191	1	295	0	57.0	7.3
7	79.1	76.7	69.8	67.9	209	1	334	0	59.3	7.1
8	79.3	77.0	69.8	67.9	273	0	343	0	58.4	6.0
10	79.2	76.7	70.1	68.5	232	0	280	0	57.7	6.6
11	79.2	76.8	69.3	67.1	220	0	262	2	57.5	5.7
12	79.2	76.8	69.6	67.6	227	5	264	0	56.2	6.8
13	79.4	77.0	69.7	67.6	240	0	265	0	59.6	5.4
14	79.3	77.1	69.5	67.6	269	0	289	0	59.3	4.9
15	79.3	77.1	69.6	67.8	284	1	292	0	57.2	5.4
16	79.3	77.1	69.5	67.7	290	0	287	0	57.6	5.8
17	79.4	77.3	69.6	67.7	282	1	268	1	58.7	5.9
18	79.2	77.0	69.5	67.5	303	0	306	0	58.0	5.5
19	79.5	77.6	69.9	68.2	344	0	322	1	56.6	6.0
20	79.4	77.4	69.5	67.6	290	5	266	0	57.0	6.7
35	79.3	77.0	69.5	67.6	309	0	295	0	59.8	6.1
39	79.1	76.6	69.2	66.9	222	1	325	0	59.1	6.1
40	79.2	76.8	69.3	67.1	255	3	301	0	58.8	4.8
41	79.3	77.1	69.4	67.3	335	0	328	0	58.5	5.4
42	79.2	76.8	69.2	66.9	268	0	290	0	58.6	5.5

LOCATION: E. ISELIN PKWY. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
43	79.3	77.1	69.1	66.8	283	0	363	0	58.8	5.6
54	79.3	77.1	69.1	66.6	203	0	362	0	59.7	6.4
56	79.4	77.3	69.0	66.4	208	0	379	0	59.5	5.8
57	79.3	77.0	68.9	66.3	206	1	375	1	60.4	6.2
61	79.4	77.4	69.1	66.6	274	0	342	0	60.2	6.0
63	79.5	77.5	69.2	66.9	283	0	264	2	58.2	5.1

LOCATION: E. ISELIN PKWY. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
6	79.2	76.6	65.2	63.4	196	1	365	0	58.2	5.8
9	79.3	77.2	65.7	63.8	225	1	389	0	58.7	6.1
10	79.2	76.9	65.5	63.7	223	3	407	0	57.6	6.4
28	79.5	77.6	68.7	65.9	240	0	405	0	59.1	5.5
29	79.6	77.5	68.4	65.5	237	0	475	0	57.8	6.1
32	79.5	77.3	68.0	65.1	206	1	415	0	58.0	5.8
34	79.5	77.5	68.6	65.7	238	0	444	0	57.7	5.0
35	79.9	77.9	68.5	65.7	244	1	322	0	57.9	5.8
37	79.4	77.0	67.0	64.5	201	0	228	1	57.4	6.9
50	79.4	77.3	67.3	64.8	279	2	310	0	59.4	6.3
51	79.3	77.1	67.0	64.6	268	0	260	0	59.6	5.2
52	79.3	77.0	67.0	64.6	283	2	285	1	59.5	5.5
53	79.3	76.9	66.3	64.2	243	2	306	0	58.5	5.9
56	79.2	76.9	67.2	64.7	270	0	331	0	58.7	5.1
60	79.4	77.2	66.5	64.2	270	0	343	0	56.7	5.9
62	79.5	77.4	67.5	64.8	342	0	371	0	56.5	4.9
63	79.4	77.2	68.3	65.3	299	0	396	0	57.5	4.9
65	79.3	77.0	66.8	64.4	265	0	299	0	56.1	5.1
67	79.5	77.2	67.7	64.8	296	0	363	0	56.8	5.2
69	79.5	77.4	67.7	65.0	267	0	364	0	56.5	6.6
71	79.6	77.3	68.0	65.1	222	1	369	0	58.8	6.4
72	79.4	77.1	67.1	64.6	209	2	371	0	58.1	5.6

LOCATION: E. ISELIN PKWY. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
78	79.6	77.6	67.9	65.1	252	1	378	0	56.2	6.7
79	79.6	77.6	68.3	65.4	258	1	342	0	56.2	5.9
83	79.4	77.3	68.0	65.2	273	1	307	0	56.8	5.9
84	79.5	77.5	68.7	65.9	295	0	300	0	56.7	5.7
85	79.6	77.6	68.5	65.6	283	0	257	0	59.6	6.1

LOCATION: MAPLE ST. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
2	74.8	73.2	62.5	60.0	327	0	276	0	N/A	N/A
5	74.4	72.6	62.0	59.6	304	0	257	0	N/A	N/A
7	78.5	75.7	64.0	61.5	256	0	231	0	N/A	N/A
10	75.0	73.3	64.2	62.4	302	0	225	0	N/A	N/A
13	74.6	72.8	61.1	59.6	239	0	232	0	N/A	N/A
18	75.1	73.4	63.5	60.7	294	0	222	3	N/A	N/A
23	75.2	73.6	61.0	59.5	314	7	243	0	N/A	N/A
25	75.0	73.4	59.7	58.0	320	0	235	2	N/A	N/A
30	76.4	74.3	61.8	59.5	300	1	235	1	N/A	N/A
31	83.4	80.5	64.1	61.7	326	0	224	0	57.2	5.1
33	83.8	81.1	64.2	61.8	325	0	199	0	57.3	6.0
38	83.7	80.7	64.5	62.5	349	3	267	0	56.2	5.6
39	83.6	80.6	64.5	62.5	307	0	266	0	57.0	5.8
40	83.4	80.4	64.6	62.5	433	0	306	1	56.2	5.3
52	84.0	81.4	64.4	62.4	354	0	272	0	N/A	N/A
53	83.8	81.0	64.3	62.1	389	0	289	0	N/A	N/A
55	83.9	81.2	64.5	62.6	395	1	279	1	N/A	N/A
57	83.8	81.0	64.2	62.0	354	0	286	0	N/A	N/A
58	84.0	81.4	64.4	62.4	321	0	354	1	N/A	N/A
60	84.0	81.4	64.7	62.9	379	0	302	1	51.1	5.8
64	84.1	81.6	64.5	62.7	351	2	205	0	56.0	5.3
65	83.9	81.3	64.6	62.8	352	1	197	0	54.3	6.1

LOCATION: MAPLE ST. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
66	78.0	75.2	59.7	57.9	321	0	224	0	N/A	N/A
74	83.8	80.9	64.4	62.4	263	0	261	1	56.8	5.1
75	83.7	80.9	64.7	63.1	280	1	256	0	55.7	5.3
76	83.8	81.0	64.5	62.6	271	2	255	0	55.9	6.2
79	83.8	81.1	64.4	62.5	300	0	296	0	56.5	5.7
80	83.9	81.2	64.5	62.7	331	3	270	0	54.7	5.6
81	83.9	81.2	64.4	62.4	298	1	269	0	56.8	6.2

LOCATION: MAPLE ST. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
8	74.5	72.7	65.4	61.0	315	0	241	0	N/A	N/A
13	83.3	80.2	59.4	57.3	254	2	298	0	58.2	6.3
14	84.1	81.6	59.8	58.0	289	1	308	1	59.4	6.0
20	83.8	81.0	61.2	59.1	309	0	321	0	59.1	5.6
32	84.2	81.9	63.9	61.2	327	3	541	0	59.2	5.8
34	84.1	81.6	63.4	60.6	297	0	361	1	58.8	5.7
38	84.2	81.8	61.1	59.1	347	1	242	0	N/A	N/A
39	84.2	81.8	59.9	58.2	292	0	277	0	N/A	N/A
40	84.3	82.2	61.8	59.5	327	2	276	0	N/A	N/A
41	84.4	82.3	63.2	60.4	313	3	287	0	N/A	N/A
44	84.3	82.2	60.7	58.9	373	0	264	1	N/A	N/A
45	84.2	82.0	60.9	59.0	332	3	296	0	N/A	N/A
59	83.6	80.7	62.6	59.8	299	2	201	0	N/A	N/A
61	83.8	80.9	61.4	59.3	276	2	224	0	N/A	N/A
63	83.9	81.2	61.5	59.4	297	2	235	1	N/A	N/A
67	83.9	81.3	63.7	60.8	443	0	260	2	N/A	N/A
69	83.7	80.9	63.5	60.7	457	0	278	0	N/A	N/A
70	84.0	81.4	64.2	61.9	519	0	320	0	N/A	N/A
71	83.8	81.1	64.1	61.8	509	2	306	1	N/A	N/A
73	83.8	81.0	62.3	59.8	324	1	305	0	N/A	N/A
74	84.0	81.4	63.3	60.5	335	1	290	0	N/A	N/A
82	84.0	81.3	63.5	60.7	303	0	379	1	N/A	N/A

LOCATION: MAPLE ST. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
83	84.1	81.7	64.0	61.5	348	1	293	2	N/A	N/A
89	84.0	81.5	64.1	61.8	455	1	341	0	N/A	N/A

LOCATION: E. PINE ST. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
2	79.2	76.7	69.1	66.8	223	2	324	2	N/A	N/A
3	79.3	77.0	69.3	67.4	253	0	337	0	N/A	N/A
4	79.3	77.0	69.3	67.3	277	1	303	0	N/A	N/A
5	79.2	76.8	69.4	67.5	256	2	302	0	N/A	N/A
6	79.2	76.9	69.4	67.3	264	7	293	0	N/A	N/A
9	78.8	76.1	69.0	66.4	217	0	314	0	N/A	N/A
10	79.1	76.7	69.5	67.4	265	0	314	0	N/A	N/A
11	78.9	76.1	69.0	66.4	234	0	380	0	N/A	N/A
14	78.8	76.0	69.1	66.7	219	0	373	0	N/A	N/A
15	78.8	75.9	69.1	66.6	216	0	370	1	N/A	N/A
16	79.0	76.2	68.9	66.3	218	0	338	0	N/A	N/A
19	78.8	75.9	69.2	66.9	194	0	375	0	N/A	N/A
22	79.1	76.5	69.4	67.4	233	0	258	1	N/A	N/A
24	79.3	76.8	69.2	66.9	253	2	262	0	N/A	N/A
27	79.2	76.7	69.6	67.7	249	1	271	0	N/A	N/A
30	79.1	76.7	69.3	67.2	281	0	320	2	N/A	N/A
32	78.9	76.3	69.0	66.4	198	3	335	0	N/A	N/A
35	78.7	75.9	68.6	65.7	225	0	329	0	N/A	N/A
39	78.9	76.3	68.4	65.6	242	0	307	0	N/A	N/A
40	79.0	76.3	67.9	65.0	239	1	289	0	N/A	N/A
42	78.8	75.9	67.6	64.9	236	1	319	0	N/A	N/A
43	78.8	76.0	68.6	65.8	252	0	346	0	N/A	N/A

LOCATION: E. PINE ST. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
45	79.0	76.4	68.4	65.6	250	2	286	0	N/A	N/A
48	79.0	76.5	68.3	65.4	280	1	300	0	N/A	N/A
49	79.0	76.4	69.0	66.5	268	3	330	0	N/A	N/A
50	79.0	76.4	68.5	65.7	275	3	294	0	N/A	N/A
54	78.9	76.3	67.2	64.6	280	0	370	1	N/A	N/A
55	79.0	76.5	65.9	63.9	303	0	385	2	N/A	N/A
56	78.9	76.0	66.1	64.0	272	0	401	0	N/A	N/A
57	78.5	75.5	65.0	63.3	224	0	404	1	N/A	N/A
58	78.5	75.3	65.2	63.4	209	0	401	1	N/A	N/A
60	78.8	75.9	65.0	63.2	153	0	373	1	N/A	N/A
61	78.7	75.8	64.5	62.7	236	0	299	0	N/A	N/A
63	78.6	75.7	65.6	63.8	233	0	293	1	N/A	N/A
64	78.8	76.1	67.2	64.7	249	0	305	2	N/A	N/A
66	78.6	75.8	64.9	63.2	262	0	275	0	N/A	N/A
70	78.9	76.2	65.4	63.5	280	0	311	1	N/A	N/A
71	78.9	76.3	66.4	64.2	255	1	348	2	N/A	N/A
73	79.2	76.7	68.5	65.6	267	2	314	0	N/A	N/A
74	79.1	76.5	68.6	65.8	259	1	331	3	N/A	N/A
76	79.1	76.6	68.7	66.0	247	0	377	1	N/A	N/A
78	79.2	76.7	68.8	66.0	283	1	340	0	N/A	N/A
79	79.2	76.8	68.6	65.8	252	0	344	0	N/A	N/A
82	79.6	77.5	69.3	66.9	288	11	341	2	N/A	N/A

LOCATION: E. PINE ST. FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
83	79.4	77.2	68.8	66.1	333	1	349	0	N/A	N/A
86	79.4	77.3	69.1	66.7	338	0	353	0	N/A	N/A
88	79.4	77.3	69.1	66.7	335	2	348	0	N/A	N/A

LOCATION: E. PINE ST. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
3	79.1	76.7	64.3	62.3	296	1	387	1	N/A	N/A
6	79.1	76.6	64.3	62.1	281	1	390	1	N/A	N/A
7	79.4	77.1	64.5	62.4	264	4	378	1	N/A	N/A
8	79.2	76.8	64.4	62.3	279	4	323	1	N/A	N/A
9	79.2	76.8	64.4	62.6	243	3	392	0	N/A	N/A
10	79.2	77.1	64.5	62.7	307	0	342	2	N/A	N/A
12	79.3	77.1	64.5	62.5	292	1	329	0	N/A	N/A
13	79.0	76.4	64.1	61.7	231	2	314	1	N/A	N/A
15	79.3	77.1	64.4	62.4	277	2	284	0	N/A	N/A
18	79.2	76.9	64.2	62.0	250	2	297	5	N/A	N/A
20	79.2	76.9	64.2	62.1	269	1	307	1	N/A	N/A
22	79.1	76.5	63.8	61.0	233	0	338	0	N/A	N/A
24	79.2	76.7	64.0	61.5	206	0	351	0	N/A	N/A
26	79.0	76.1	63.2	60.4	188	1	294	1	N/A	N/A
51	79.1	76.7	63.9	61.2	252	0	262	0	55.9	5.9
53	79.4	77.1	64.1	61.7	237	0	290	3	57.8	5.5
55	79.4	77.4	64.2	61.9	281	0	284	0	58.3	5.7
56	79.3	77.0	63.9	61.2	268	3	278	0	58.4	5.8
58	79.5	77.5	64.1	61.6	294	0	277	1	57.9	5.8
59	79.4	77.4	64.0	61.6	313	3	311	1	57.4	5.1
61	79.9	78.1	68.1	65.3	256	0	294	4	N/A	N/A
63	81.1	78.8	68.3	65.4	243	0	262	2	N/A	N/A

LOCATION: E. PINE ST. FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
66	79.6	77.6	66.4	64.3	226	2	286	1	N/A	N/A
67	80.6	78.6	68.5	65.7	244	0	294	0	N/A	N/A
68	80.7	78.8	66.8	64.5	269	1	268	0	N/A	N/A
69	80.3	78.3	67.4	64.8	250	0	276	0	N/A	N/A
71	80.7	78.8	68.6	65.8	299	1	272	0	N/A	N/A
73	82.6	79.8	68.9	66.2	328	0	359	0	N/A	N/A
75	81.0	79.0	68.5	65.6	284	2	321	0	N/A	N/A
76	80.0	78.1	68.2	65.4	273	0	319	0	N/A	N/A

LOCATION: SUNSET DRIVE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
1	73.8	70.9	69.1	66.5	265	0	175	3	N/A	N/A
2	73.2	70.1	69.7	67.5	213	0	238	3	N/A	N/A
3	73.8	70.9	69.3	67.0	230	3	252	1	N/A	N/A
4	73.8	70.8	69.3	66.9	225	0	251	4	N/A	N/A
6	73.9	71.1	69.8	67.7	254	1	239	0	N/A	N/A
8	74.1	71.6	69.9	68.1	N/A	N/A	N/A	N/A	N/A	N/A
9	74.0	71.3	69.6	67.7	313	1	209	0	N/A	N/A
10	74.1	71.6	69.9	68.1	273	4	194	1	N/A	N/A
11	74.1	71.5	70.3	68.5	269	3	204	1	N/A	N/A
12	73.6	70.7	69.5	67.6	286	0	196	0	N/A	N/A
13	73.4	70.5	69.9	68.1	240	0	248	0	N/A	N/A
14	73.5	70.6	70.7	69.1	212	1	229	0	N/A	N/A
15	73.6	70.7	70.8	69.0	247	1	225	3	N/A	N/A
16	73.3	70.3	69.5	67.3	217	6	221	2	N/A	N/A
17	73.6	70.7	69.7	67.8	267	3	228	2	N/A	N/A
18	73.5	70.6	69.7	67.9	248	4	225	1	N/A	N/A
19	73.6	70.7	69.6	67.6	279	0	274	3	N/A	N/A
29	74.1	71.6	69.9	68.2	296	0	224	0	N/A	N/A
30	74.1	71.5	69.5	67.6	310	1	249	0	N/A	N/A
32	74.0	71.5	69.4	67.6	337	1	229	0	N/A	N/A
33	74.2	71.7	69.7	67.9	277	9	240	0	N/A	N/A
36	74.1	71.8	69.6	67.9	322	2	210	0	N/A	N/A

LOCATION: SUNSET DRIVE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
37	74.0	71.3	69.8	67.8	279	2	209	1	N/A	N/A
49	73.7	71.0	69.8	68.3	244	0	225	0	N/A	N/A
51	73.4	70.5	69.6	67.8	263	1	241	1	N/A	N/A
54	74.0	71.3	69.3	67.3	212	0	284	0	N/A	N/A
55	74.1	71.6	69.5	67.6	290	1	204	0	N/A	N/A
56	74.1	71.6	69.3	67.3	317	2	276	0	N/A	N/A
57	74.1	71.7	69.2	67.0	330	0	315	0	N/A	N/A
60	73.9	71.3	69.7	67.9	295	1	257	0	N/A	N/A
61	74.1	71.6	69.7	67.8	307	1	252	0	N/A	N/A
62	74.0	71.4	69.4	67.6	304	0	235	1	N/A	N/A
63	74.1	71.6	69.5	67.7	326	1	242	0	N/A	N/A
69	74.2	72.0	69.7	67.9	323	2	219	0	N/A	N/A
70	74.3	72.2	70.5	68.7	353	1	258	0	N/A	N/A

LOCATION: SUNSET DRIVE FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
2	78.6	75.8	64.5	62.6	367	0	226	1	69.8	6.0
3	78.6	75.8	64.6	62.8	356	0	219	0	68.3	5.6
4	78.3	75.4	64.4	62.3	370	1	222	0	68.4	6.7
5	78.5	75.6	64.4	62.7	374	1	239	2	68.5	5.8
6	78.5	75.6	64.4	62.3	399	1	196	0	67.9	6.1
7	78.5	75.6	64.4	62.3	411	0	221	0	68.4	5.5
12	78.5	75.6	64.3	62.3	292	1	206	0	68.8	6.3
13	78.7	75.9	64.5	62.6	293	2	252	0	68.9	6.9
14	78.3	75.2	64.3	62.2	256	0	263	0	69.0	5.9
17	79.0	76.4	64.4	62.4	317	2	233	0	67.0	8.0
18	78.8	76.0	64.3	62.2	303	1	253	2	69.0	6.3
19	78.3	75.4	64.4	62.4	425	0	221	0	63.9	6.3
22	76.7	74.3	64.3	62.2	415	0	158	0	61.5	5.9
29	78.0	75.1	64.3	62.1	279	1	220	0	63.9	6.1
30	78.1	75.1	64.1	61.8	298	2	226	0	63.0	6.2
35	77.6	74.9	64.3	62.3	285	1	222	0	55.4	6.2
42	78.8	76.1	64.5	62.7	323	2	258	3	57.8	5.9
43	78.7	76.0	64.5	62.8	346	0	239	0	56.2	5.5
45	78.8	76.0	64.6	62.7	352	1	253	0	56.1	6.7
48	78.8	76.0	64.5	62.7	313	0	284	1	57.2	5.8
55	79.3	77.3	64.4	62.4	362	1	223	4	62.9	6.6
57	79.2	77.0	64.2	62.0	351	0	231	0	63.9	6.4

LOCATION: SUNSET DRIVE FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
58	79.3	77.1	64.3	62.2	333	1	282	2	63.4	5.7
62	78.7	75.7	64.0	61.5	293	1	229	0	63.6	6.5
64	78.6	75.7	64.0	61.4	292	0	231	0	62.7	6.6
67	78.6	75.7	63.8	61.1	302	0	234	3	64.4	5.5

LOCATION: CONTROL SITE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
4	81.3	79.1	69.9	68.1	202	1	184	0	61.8	6.8
5	82.4	79.7	73.2	70.4	217	1	245	0	60.4	8.0
6	82.6	79.8	71.8	69.5	239	0	197	0	62.8	5.9
19	82.5	79.7	72.2	69.7	183	1	203	0	61.1	7.0
20	81.9	79.5	69.8	68.1	235	0	211	0	60.5	6.7
22	82.1	79.5	73.1	70.3	236	0	250	0	N/A	N/A
25	82.9	80.0	73.4	70.5	250	0	257	1	N/A	N/A
26	81.8	79.3	72.6	69.9	237	1	264	2	N/A	N/A
30	81.4	79.1	70.0	68.4	211	0	243	0	N/A	N/A
32	83.0	80.1	70.2	68.5	221	0	248	0	N/A	N/A
38	83.5	80.6	70.8	69.0	242	2	227	1	N/A	N/A
39	83.1	80.2	70.1	68.4	230	0	238	1	N/A	N/A
41	81.8	79.4	72.2	69.7	216	0	239	1	N/A	N/A
42	82.2	79.5	70.9	68.9	247	0	224	0	N/A	N/A
43	81.4	79.1	69.9	68.1	230	0	248	1	N/A	N/A
44	82.6	79.9	69.9	68.2	256	0	235	0	N/A	N/A
45	82.4	79.6	70.2	68.5	239	0	232	0	N/A	N/A
49	81.9	79.3	70.3	68.5	250	0	233	0	N/A	N/A
50	81.4	79.0	70.4	68.6	257	0	266	0	N/A	N/A
66	80.6	78.4	68.4	65.6	241	0	245	0	60.0	8.0
67	81.4	78.9	69.0	66.4	218	0	259	3	60.5	6.5
69	81.1	78.7	68.4	65.5	230	0	218	0	57.8	6.7

LOCATION: CONTROL SITE FIELD POSITION NO.1

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
70	80.7	78.5	68.6	65.7	191	0	220	1	59.2	7.3
71	81.8	79.2	68.9	66.1	237	0	297	0	60.7	6.4
72	82.7	79.9	69.1	66.7	292	0	262	1	61.3	7.2
73	82.3	79.4	69.0	66.4	258	0	256	0	61.1	7.2
74	82.2	79.6	69.8	68.1	245	0	210	0	59.4	7.2
76	82.9	79.9	70.2	68.5	279	0	234	0	58.1	6.4
77	83.2	80.4	70.4	68.7	256	0	223	0	57.4	7.0
79	82.2	79.6	69.6	67.8	296	0	250	0	57.1	6.5
84	82.7	79.8	70.2	68.5	218	0	284	0	61.4	8.3
86	83.1	80.2	71.5	69.3	254	1	273	0	61.9	5.8
87	83.1	80.1	71.4	69.2	233	1	297	0	60.6	6.4
88	82.7	79.9	70.9	69.0	243	0	298	2	60.7	7.2
89	83.7	80.8	73.0	70.2	247	0	291	2	60.8	6.5
90	82.8	80.0	70.8	68.9	237	0	274	0	61.2	7.2
92	83.5	80.6	72.7	69.9	266	0	317	0	58.8	7.2
108	81.6	79.1	69.5	67.4	219	0	230	1	61.0	7.6
111	81.5	78.9	69.2	66.8	200	0	236	0	63.0	6.4
113	82.8	79.8	69.4	67.4	232	0	238	0	61.7	7.1

LOCATION: CONTROL SITE FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
3	83.7	80.8	66.2	64.2	255	1	426	0	67.3	6.5
4	83.5	80.6	66.2	64.2	247	0	435	0	65.2	6.9
12	82.1	79.4	67.1	64.6	248	1	188	0	62.9	6.7
14	81.5	79.0	65.9	64.0	201	1	208	1	64.5	7.0
17	82.7	79.9	68.6	65.8	240	1	301	3	63.8	6.9
21	82.4	79.8	66.1	64.1	250	0	292	2	65.3	6.3
23	83.2	80.2	67.3	64.8	264	0	287	0	63.8	5.5
24	83.4	80.5	68.7	66.0	285	2	273	0	65.1	7.1
25	82.5	79.8	65.9	64.0	234	2	252	2	64.6	6.1
26	83.1	80.2	68.3	65.4	259	0	293	1	65.6	7.3
27	83.3	80.4	66.7	64.4	274	2	323	0	64.4	6.3
28	82.8	80.0	68.2	65.4	266	1	330	0	64.7	7.1
29	83.6	80.7	69.1	66.7	302	0	376	0	67.2	7.1
30	83.4	80.5	68.7	66.0	282	0	355	0	65.4	5.8
35	82.6	79.6	65.7	63.8	225	1	190	1	56.8	7.5
37	82.3	79.4	65.5	63.7	186	0	208	1	59.4	6.9
39	82.7	79.8	66.8	64.5	201	0	219	1	58.1	7.4
43	82.5	79.6	66.1	64.2	179	2	252	0	57.6	6.7
49	81.8	79.3	64.8	63.1	234	0	276	0	56.7	7.0
52	83.4	80.4	66.7	64.4	255	0	290	1	57.4	6.7
54	83.4	80.5	65.2	63.5	268	0	297	0	58.2	7.1
57	83.9	81.2	68.6	65.8	319	0	279	0	56.6	7.4

LOCATION: CONTROL SITE FIELD POSITION NO.2

	NOISE LEVELS				TRAFFIC VOLUME				SPEED DATA	
	REFERENCE		FIELD		NEAR LANES		FAR LANES			
OBS	L10 (DBA)	LEQ (DBA)	L10 (DBA)	LEQ (DBA)	CARS	TRUCKS	CARS	TRUCKS	SPEED (MPH)	STD DEV (MPH)
58	83.9	81.2	68.3	65.4	289	0	333	0	57.7	6.3
59	83.7	81.0	68.2	65.4	304	0	302	0	N/A	N/A
60	83.9	81.2	68.5	65.7	288	0	303	0	60.4	6.4

APPENDIX D

D.2 Weather Data

LOCATION: JAMES PLACE FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: S

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg.F/Deg. C)	Relative Humidity (%)
8/31/76	12:50 p.m.	1-3	< 1	SE	73.5/23	39
	1:15 p.m.	4-9	2-3	SW	74/23.5	39
	2:05 p.m.	10-13	.5	W	78.5/26	31
	2:40 p.m.	13-20	2	SW	77/25	31
9/1/76	12:35 p.m.	21-23	6-6.5	NW	82/28	42
	1:06 p.m.	23-30	4.5	W	83.5/28.5	40
	2:10 p.m.	31-34	2	S	83/28.5	42
	2:40 p.m.	35-40	3-4	W	84.5/29	39
9/3/76	12:15 p.m.	41-42	< 1	E	69.5/21	54
	12:45 p.m.	43-47	0-1	SE	69/20.5	54
	1:18 p.m.	48-50	1	NW	71.5/22	49
	1:36 p.m.	51-52	0	--	71/21.5	49
	2:00 p.m.	53-60	0	--	72/22	44
9/13/76	11:05 a.m.	61-64	3	W	84/29	38
	12:15 p.m.	65-67	0	--	85/29.5	38
	12:45 p.m.	68-70	1	SW	87/30.5	39
	1:15 p.m.	71-73	2.5	SW	88/31	36
	1:55 p.m.	74-80	2	W	89.5/32	29

1. 8 point resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.

LOCATION: JAMES PLACE FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: S

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg.F/Deg. C)	Relative Humidity (%)
9/9/76	11:50 a.m.	1-3	2-3	S	80/26.5	48
	12:20 p.m.	4-10	1.5-2	E	78/25.5	55
	1:45 p.m.	11-13	4-5.5	E	76/24.5	61
	2:20 p.m.	14-20	1	SW	76/24.5	55
9/15/76	11:45 a.m.	21-22	0	--	80/26.5	52
	12:15 p.m.	23-30	N/A	N/A	80/26.5	59
	1:50 p.m.	31-33	2.5	SE	77.5/25.5	77 (?)
	2:20 p.m.	34-40	1	S	77.5/25.5	61
9/23/76	1:10 p.m.	41-43	3-8	W	73.5/23	37
	1:40 p.m.	44-50	2-5	W	75/24	47
	2:40 p.m.	51-53	3	W	76/24.5	32
	3:00 p.m.	54-55	3.5	NW	76/24.5	33
9/28/76	11:05 a.m.	56-57	8[3]	W	71/21.5	59
	11:35 a.m.	58-64	3.5	SW	69/20.5(?)	52
	12:30 p.m.	65-69	0-1	NW	72/22	52
	12:55 p.m.	69-75	0-1	N	69/20.5(?)	54
12/2/76	11:45 a.m.	1'-3'[4]	3.5	E	43/6	59
	12:15 p.m.	4'-10'[4]	4.5	SE	41/5	60
	1:45 p.m.	11'-13'[4]	3	W	44/6.5	49
	2:15 p.m.	14'-20'[4]	4	W	42/5.5	54
12/9/76	11:15 a.m.	21'-23'[4]	5	W	35/1.5	49
	11:45 a.m.	24'-30'[4]	6	NW	35/1.5	50
	1:30 p.m.	31'-33'[4]	3	NW	31/-.5	39
	2:05 p.m.	33'-40'[4]	3.5	NW	32/0	39

1. 8 point resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.
3. Gusting
4. These observations were taken under a different sample number, and therefore follow a different sequence.

LOCATION: E. LOUIS PLACE FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: N

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
6/29/76	12:55 p.m.	1-3	< 1	NW	80.5/27	68
	1:25 p.m.	4-9	< 1	NW	80/26.5	69
	2:25 p.m.	10-11	0-2	NW	83/28.5	59
	3:00 p.m.	12-14	0-2	NE	84.5/29	56
6/30/76	11:30 a.m.	15-16	4	S	81/27	81
7/1/76	12:50 p.m.	17-19	0-1	W	81.5/27.5	49
	1:20 p.m.	20-26	0-1	N	82/28	49
	2:40 p.m.	27-32	1	NE	81/27	54
7/2/76	11:10 a.m.	33-36	2.5	NW	77/25	59
	11:40 a.m.	37-42	< 1	E	76.5/24.5	51
	1:11 p.m.	43-46	0-1.5	NW	80/26.5	42
	1:37 p.m.	47-52	2	NW	80.5/27	44
7/6/76	10:35 a.m.	53-55	0-1	SW	81/27	47
	11:10 a.m.	56-64	0-.5	NW	83/28.5	43
	12:45 p.m.	65-67	1	NW	86.5/30.5	37
	1:15 p.m.	68-72	1	E	87.5/31	36

1. 8 point resolution
2. 1 Knot ≈1.15 mph≈ 1.85 km/hr.

LOCATION: E. LOUIS PLACE FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: N

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg.F/Deg. C)	Relative Humidity (%)
7/6/76	1:52 p.m.	1-2	1	W	89/31.5	41
	2:35 p.m.	3-7	1	W	89/31.5	40
7/8/76	11:07 a.m.	8-10	0-1	NE	76/24.5	70
	11:45 a.m.	11-15	1-2	NE	77/25	68
	1:20 p.m.	16-17	1	NE	80/26.5	66
	2:00 p.m.	18-24	2	NE	80/26.5	68
7/9/76	11:10 a.m.	25-26	0-1	NW	79/26	60
	11:45 a.m.	27-31	.5-1.5	SW	83/28.5	54
	12:10 p.m.	32-34	0-1	SW	83/28.5	56
	1:40 p.m.	35-37	1	SE	82/28	51
	2:10 p.m.	38-45	0-1	NW	83.5/28.5	47
7/12/76	11:20 a.m.	46-47	2-2.5	W	79/26	60
	11:45 a.m.	48-55	2-3	NW	81/27	52
	1:20 p.m.	56-58	0-1	SW	84.5/29	43
	1:50 p.m.	59-65	1-2	SW	84/29	43

1. 8 point resolution
2. 1 Knot ≈1.15 mph ≈ 1.85 km/hr.

LOCATION: E. ISELIN PKWY. FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: N

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
7/14/76	12:35 p.m.	1-3	5	NW	76/24.5	58
	1:05 p.m.	4-9	4	W	76/24.5	54
	2:00 p.m.	10-13	2.5	NW	77.5/25.5	52
	2:25 p.m.	13-17	6	NW	78/25.5	52
	2:50 p.m.	17-20	5	NW	78.5/26	52
7/15/76	1:05 p.m.	21-22	4	NW	81/27	44
	1:35 p.m.	23-30	0-1	W	82/28	45
	2:50 p.m.	31-33	2-2.5	NW	84/29	40
7/16/76	10:40 a.m.	34-37	0-1	S	76/24.5	73
	11:30 a.m.	38-43	1	E	77.5/25.5	68
7/19/76	11:05 a.m.	44-46	2	NW	83/28.5	40
	11:40 a.m.	47-53	2	NW	83/28.5	43
	1:10 p.m.	54-56	< 1	NW	86/30	32
	2:01 p.m.	57-63	1-2	NW	89/31.5	31

1. 8 point resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.

LOCATION: E. ISELIN PKWY. FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: N

Date	Time	Corresponding Observations	Wind Speeds (knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
7/20/76	10:50 a.m.	1-3	0	--	83/28.5	49
	11:25 a.m.	4-10	2	W	85/29.5	44
	1:00 p.m.	11-12	3-4	N[3]	86.5/30.5	41
	1:35 p.m.	13-20	0	--	87/30.5	40
	2:40 p.m.	21-23	2	SW	90/32	39
	3:05 p.m.	24-25	2.5	W	90.5/32.5	38
7/21/76	10:40 a.m.	26-27	0-.5	NW	82/28	55
	11:20 a.m.	28-35	3-3.5	W	83/28.5	56
	12:30 p.m.	36-39	3	NW	84.5/29	51
7/22/76	11:20 a.m.	40-41	3	NE	78/25.5	59
	11:50 a.m.	42-49	3	E	78/25.5	49
	1:35 p.m.	50-51	3	NE	78/25.5	49
	2:00 p.m.	52-55	4	NE	80/26.5	49
	2:26 p.m.	56-59	2	E	80/26.5	49
7/26/76	10:40 a.m.	60-62	2-2.5	E	74/23.5	42
	11:20 a.m.	63-69	4.5	E	75/24	43
	12:30 p.m.	70	3-4	SE	77/25	34
	1:05 p.m.	71-78	1	SE	79/26	35
	2:05 p.m.	79-83	2-3	NE	80/26.5	28
	2:35 p.m.	84-89	< 1	W	81/27	28

1. 8 point resolution
2. 1 Knot = 1.15 mph = 1.85 km/hr.

LOCATION: MAPLE STREET FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: SW

Date	Time	Corresponding Observations	Wind Speeds (knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
7/27/76	10:30 a.m.	1-3	3	NW	84/29	64
	11:10 a.m.	4-10	3	SW	81/27	63
	12:40 p.m.	11-13	3	W	86/30	55
	1:20 p.m.	14-20	3	W	89.5/32	50
7/28/76	11:30 a.m.	21-22	1	NE	85/29.5	46
	12:00 Noon	23-30	2	SE	88/31	42
	1:40 p.m.	31-33	2	N	88/31	46
	2:10 p.m.	34-37	2	N	92.5/33.5	36
	2:30 p.m.	38-40	2	N	92.5/33.5	39
8/2/76	11:30 a.m.	41-43	2-3	E	76/24.5	34
	12:00 Noon	44-50	4	E	75.5/24	36
	1:30 p.m.	51-52	1-2	N	78.5/26	29
	2:00 p.m.	53-60	2	E	78/25.5	27
8/3/76	11:45 a.m.	61-62	2[3]	N	79/26	41
	12:15 p.m.	63-70	2[3]	SW	79.7/26.5	36
	1:45 p.m.	71-73	< 1[3]	NE	80/26.5	38
	2:20 p.m.	73-80	< 1[3]	SW	79/26	40

1. 8 point resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.
3. Wind Gusting to 5-6 knots

LOCATION: MAPLE STREET FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: SW

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
8/4/76	10:45 a.m.	1-4	3	E	79/26	46
	11:40 a.m.	5-10	4.5	W	79/26	43
	2:00 p.m.	11-15	3.5	NW	81/27	35
	2:55 p.m.	16-20	4.5	W	83/28.5	33
8/5/76	12:50 p.m.	21-22	5.5	NW	85/29.5	39
	1:40 p.m.	23-30	3-3.5	NW	85/29.5	38
	2:50 p.m.	31-35	2.5-4	SW	88/31	37
8/6/76	12:30 p.m.	36-38	2	NW	93/34	48
	1:15 p.m.	39-45	0	--	95/ 35	51
	2:00 p.m.	46-48	3.5	NE	92/33.5	46
	2:30 p.m.	49-55	1	NW	90.5/32.5	47
8/12/76	12:35 p.m.	56-58	2	NW	85/29.5	56
	1:00 p.m.	58-65	0	--	85/29.5	50
	2:07 p.m.	66-67	2.5	W	86/30	53
	2:30 p.m.	68-72	4	SE	88/31	49
8/13/76	1:00 p.m.	73-76	4.5	W	90/32	54
	1:30 p.m.	77-82	< 1	E	91/33	51
	2:25 p.m.	83-86	2-2.5	SE	90.5/32.5	48
	2:50 p.m.	86-89	0-1	S	91.5/33	50

1. 8 Point Resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.

LOCATION: E. PINE ST. FIELD POSITION NO. 1

DIRECTION[1] NEAR TRAFFIC AT MEASUREMENT SITE: NE

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
8/16/76	1:10 p.m.	1-3	2.5-3	NW	85.5/29.5[3]	49
	1:42 p.m.	4-10	2.5	SW	76/24.5	46
8/17/76	11:25 a.m.	11-13	1	N	75/24	50
	11:55 a.m.	14-20	1	NW	75/24	54
	1:35 p.m.	21-22	3.5	E	79/26	51
	2:00 p.m.	23-26	1	N	80/26.5	50
	2:25 p.m.	27-30	< 1	N	80/26.5	47
8/18/76	12:30 p.m.	31-33	< 1	NE	78/25.5	45
	1:05 p.m.	34-39	3-3.5	SE	78/25.5	42
	1:50 p.m.	40-43	1-2	E	80.5/27	40
	2:30 p.m.	44-50	2-2.5	NW	81/27	37
8/19/76	11:20 a.m.	51-54	1-2	SE	74/23.5	45
	11:50 a.m.	55-60	2-5	E	71.5/22 (?)	44
	1:25 p.m.	61-63	5	E	75/24	39
	1:52 p.m.	64-70	3.5	E	72.5/22.5 (?)	34
8/20/76	12:35 p.m.	71-72	.5-1	W	80/26.5	50
	1:10 p.m.	73-79	.5-1	W	81/27	46
	2:00 p.m.	80-83	1-2	SW	82.5/28	51
	2:25 p.m.	84-90	0	--	83/28.5	49

1. 8 point resolution
2. 1 Knot = 1.15 mph = 1.85 km/hr.
3. Thermometer had been in area heated by sun.

LOCATION: E. PINE STREET FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: NE

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction	Temp. (Deg.F/Deg.C)	Relative Humidity (%)
8/23/76	11:00 a.m.	1-3	3	W	83.5/28.5	55
	11:30 a.m.	4-10	2	NW	82.5/28	53
	12:40 p.m.	11-13	2-2.5	W	84.5/29	47
	1:05 p.m.	14-20	.5	NW	87.5/31	43
8/24/76	12:25 p.m.	21-23	1	E	82/28	49
	1:05 p.m.	24-29	3	E	81.5/27.5	48
	1:53 p.m.	30-34	0-2	NE	84/29	49
	2:28 p.m.	35-40	0	--	86/30	49
8/26/76	12:30 p.m.	41-43	< 1	SW	89/31.5	55
	1:00 p.m.	44-47	0-1	SW	89.5/32	58
	1:30 p.m.	48-50	3	SE	91/33	57
	1:48 p.m.	51-53	1	SE	91/33	59
	2:20 p.m.	54-60	1.5-2	SE	90/32	60
8/30/76	12:50 p.m.	61	3.5	W	68.5/20.5	38
	1:35 p.m.	62-67	4.5-5	NW	69/20.5	37
	2:07 p.m.	68-70	3.5-4	NW	72/22	36
	2:30 p.m.	71-73	3-3.5	NW	72/22	32
	2:55 p.m.	74-76	5-5.5	NW	74.5/23.5	37

1. 8 point resolution
2. 1 Knot = 1.15 mph ≃ 1.85 km/hr.

LOCATION: SUNSET DRIVE FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: SW

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/ Deg. C)	Relative Humidity (%)
6/9/76	1:35 p.m.	1-2	3	W	88/31	37
	2:35 p.m.	3-7	3	SW	91/33	74(?)
6/10/76	11:37 a.m.	8-9	0	--	87/30.5	48
	12:00 Noon	10-11	2	SW	89/31.5	48
	1:00 p.m.	12-13	0	--	90/32	43
	1:30 p.m.	14-19	3	W	91/33	42
	2:16 p.m.	20-24	< 2	W	92/33.5	41
	2:50 p.m.	25-28	3	W	93/34	38
6/16/76	10:15 a.m.		2	W	82/28	65
	11:00 a.m.	29-32	1	W	84/29	59
	11:25 a.m.	33-38	3	SW[3]	85.5/29.5	61
	12:35 p.m.	39-41	3.5	SW	86/30	55
	1:02 p.m.	42-47	1-2	W	86/30	57
	1:37 p.m.	48-50	2-3	SW	88.5/31.5	55
	2:30 p.m.	51-59	3-4.5	SW	88.5/31.5	53
6/18/76	11:07 a.m.	60-61	0	--	78/28.5	74
	11:37 a.m.	62- 65	2	SW	79.5/26.5	71
	12:00 Noon	66-68	0-1	SE	79.5/26.5	72
	1:05 p.m.	69-71	0	--	80/26.5	72
	1:35 p.m.	72-77	0	--	82/28	65
	2:10 p.m.	78-80	2.5	E	80/26.5	75
	2:45 p.m.	81-84	2	E	82/28	72

1. 8 point resolution
2. 1 Knot = 1.15 mph = 1.85 km/hr.
3. Gusts from various directions

LOCATION: SUNSET DRIVE FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: SW

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C)	Relative Humidity (%)
6/23/76	12:43 p.m.	1-4	1.5	S	84.5/29	69
	1:15 p.m.	5-8	<1	SW	85.5/29.5	68
	1:55 p.m.	9-13	1.5	NE	84/29	64
	2:45 p.m.	14-18	2.5	E	84.5/29	66
6/24/76	12:05 p.m.	19-21	1-1.5	SW	87/30.5	54
	12:50 p.m.	22-27	1-2	W	90/32	54
	1:25 p.m.	28-31	2	S	90.5/32.5	52
6/25/76	11:35 a.m.	32-34	4	SW	83/28.5	65
	12:00 Noon	35-40	4	SW	81/27	65
	1:00 p.m.	41-43	0-1.5	S	82/28	62
	1:40 p.m.	44-50	3	W	82.5/28	65
6/28/76	11:05 a.m.	51-54	2	SE	85/29.5	46
	11:35 a.m.	55-59	3	W	86/30	44
	12:30 p.m.	60	1	W	87/30.5	42
	1:10 p.m.	61-62	3.5	SW	89/31.5	40
	1:45 p.m.	63-68	>1	S	90/32	39

1. 8 point resolution
2. 1 Knot ≈1.15 mph ≈1.85 km/hr.

LOCATION: CONTROL SITE FIELD POSITION NO. 1

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: NE

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg.C)	Relative Humidity (%)
10/14/76	11:00 a.m.	1-3(?)	5-7	SW	55/13	48
	11:30 a.m.	4(?)-10	9[4]	SW	56/13.5	48
	12:40 p.m.	11-13	8[4]	W	57/14	43
	1:15 p.m.	14-20	5.5-6	NW	58.5/14.5	40
10/15/76	10:30 a.m.	21-23	6	S	60/15.5	43
	11:00 a.m.	24-30	6-8	SW	60/15.5	39
10/18/76	10:50 a.m.	31-33	4	W	45/7	44
	11:10 a.m.	34-40	4-10	N	44/6.5	46
	12:45 p.m.	41-43	7-10	W	48.5/9	36
	1:10 p.m.	44-47	4.5	W	48/9	37
	1:40 p.m.	48-50	4.5[3]	W	49/9.5	34
10/19/76	11:30 a.m.	____[7]	<.5	N/A	53/11.5[5]	51
	12:00 Noon	____[7]	4	SW	48.5/9	52
	1:06 p.m.	____[7]	4	S	50/10	44
	1:30 p.m.	64-66	4.5	NW	51/10.5	51
	2:04 p.m.	67-73	3.5	SW	51.5/11	52
10/29/76	11:15 a.m.	74-77	7-10[3]	S	46.5/8	54
	11:45 a.m.	78-83	3-5[3]	SW	46.5/8	54
	1:00 p.m.	84-85	3-5[3]	SW	53/11.5	37
	1:30 p.m.	86-93	5-7[4]	N/A[6]	53/11.5	37

1. 8 point resolution
2. 1 Knot ≈ 1.15 mph ≈ 1.85 km/hr.
3. Gusting
4. Gusts to > 9 Knots
5. Thermometer had been in warm area.
6. Wind from various directions.
7. These observations were lost.

(continued)

LOCATION: CONTROL SITE FIELD POSITION NO. 1 (continued)

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg. C.)	Relative Humidity (%)
11/3/76	11:00 a.m.	94-96	8.5	SW	54.5/12.5	53
	11:33 a.m.	97-100	6	SW	54/12	53
	11:55 a.m.	101-103	4.5	SW	56/13.5	50
	12:52 p.m.	104-105	7-10	SW	55/13	47
	1:30 p.m.	106-113	3.5	SW	54/12	47

1. 8 point resolution.
2. 1 Knot ≈1.15 mph≈ 1.85 km/hr.

LOCATION: CONTROL SITE FIELD POSITION NO. 2

DIRECTION[1] OF NEAR TRAFFIC AT MEASUREMENT SITE: NE

Date	Time	Corresponding Observations	Wind Speeds (Knots[2])	Wind Direction[1]	Temp. (Deg. F/Deg.C)	Relative Humidity (%)
11/4/76	10:40 a.m.	1-3	5-5.5[3]	SW	60/15.5	60
	11:10 a.m.	4-10	0	--	56/13.5	66
	12:45 p.m.	11-13	4-4.5[4]	W	58.5/14.5	60
	1:20 p.m.	14-19	0	--	60/15.5	59
	2:01 p.m.	20-23	2-8	SW	61/16	40
	2:32 p.m.	24-27	5-6	SW	61/16	40
	2:50 p.m.	28-30	4.5	SW	60/15.5	44
11/9/76	11:00 a.m.	31-33	8-10	SW	38/3.5	56
	11:40 a.m.	34-40	6-8	SW	36/2	45
	1:00 p.m.	41-45	7-11	SW	40/4.5	60 (?)
	1:45 p.m.	45-50	5	SW	41/5	46
	2:15 p.m.	51-53	5.5	SW	41.5/5.5	37
	2:45 p.m.	54-60	7.5-11	SW	40/4.5	42

1. 8 point resolution.
2. 1 Knot ≈ 1.15 mph ≈1.85 km/hr.
3. Gusting
4. Gusts to 9 Knots

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